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REVIEW OF EDUCATIONAL RESEARCH

The purpose of the REVIEW is to report the major research findings during a designated period, organized by areas of interest. The REVIEW identifies the significant studies, summarizes them, and, within limitations of space, critically analyzes them. It seeks to present syntheses of research findings which reflect educational insight and stimulate new research.

The more active fields of educational research are reviewed every three years; the less active fields are included in alternate cycles. (See inside back cover.)

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The Natural Sciences and Mathematics

Reviews the literature for the nearly four-year period since the issuance of Vol. XXVII, No. 4, October 1957.

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FOREWORD

The review period for this issue covers a time of unprecedented change and activity in the fields of the natural sciences and mathematics. It was for this reason that the issue was moved to an earlier open position in the cycle than it was originally scheduled for, and the review period is a little less than four years rather than the usual six for most subject-matter issues.

The chapters give evidence of major efforts by professional societies, by institutions of higher learning, and by an impressive array of national committees to influence science and mathematics curriculums. Although the changes in science and mathematics, both actual and proposed, are of major proportions, this fact has not produced any pronounced shifts in the nature or amount of the related educational research produced. In fact, one is impressed by the sparsity of the evidence adduced which would either affirm or deny the efficacy of many of the large experimental programs. There is obviously a need for a more thoroughgoing consideration of evaluative techniques and procedures and for the planning of comprehensive educational research efforts as part of these experimental programs which commit vast sums of money and the time of millions of pupils.

The amount of text required to selectively but adequately describe the research and curricular programs published during the review period make it necessary to omit the "additional references" submitted by most of the authors.

The co-chairmen wish to express their deep appreciation to contributors and to all others who helped to make this sixth review of research in science and mathematics possible.

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CHAPTER I

Science in the Elementary Grades

GEORGE G. MALLINSON and JACQUELINE V. MALLINSON

WITHIN the last few years, more attention has been focused at all levels on programs of science and mathematics than in any other period of educational history. Yet, while there have been vast expenditures of time, money, and effort designed to improve science programs at the secondary and college levels, far less attention has been given elementary science. However, there is an increasing awareness of the need for "building science programs from the bottom." This awareness is reflected in some of the studies cited herein.

Although the quantity of research dealing with elementary-school science still leaves much to be desired, there is some evidence that its quality has improved within recent years. More studies now deal with the "how" of instruction and methods for improving instruction, whereas earlier studies were largely surveys. This review is concerned with the most significant of the recent studies in elementary science.

History of Elementary Science

Of the many articles which dealt with the history of elementary science, only Kuslan's (1959a), which attempts to determine the status of elementary science in the schools of Connecticut during the period 1850-1900, merits the name of research. Unfortunately, neither the published report nor the unpublished summary reveals the source of the data, but conditions of a century ago paralleled those disclosed by findings of current studies. "In the latter half of the 19th century, there was an ever-mounting pressure on the common schools to teach science, but the lack of adequately trained teachers, equipment, and suitable textbooks effectively nullified these pressures" (p. 287). It is obvious that this statement applies to elementary science in the mid-twentieth century, also.

According to Kuslan, when the State Normal School at New Britain was opened in 1850, little science was taught in elementary schools. The science taught in the normal schools was frequently titled "Familiar Science" or "Science of Common Things," a forerunner of today's General Science. Later in the century, in the early '80's, elementary science grew through the efforts of such men as Arthur Boothby Morrill and Charles D. Hine. These men who formulated this early philosophy of elementary-school science worked indefatigably through the last years of the nineteenth century to make elementary-school science a vital part of the curriculum. This effort apparently "set the pace" for the Connecticut

normal schools, for from this time forward, "All normal school graduates were expected to teach elementary science."

One difficulty faced by elementary teachers a century ago is still a problem. Shortage of equipment is described thus: "The normal schools attempted to solve this problem by means of a superficial remedy, superficial because it was aimed at eliminating a symptom, rather than curing the disease. . . . Their solution took the form of a new course in which all students constructed simple science equipment which then became the property of the future teacher, and was to be kept for use in later teaching" (p. 288). Several entrepreneurs interested in elementary science instruction made "science kits" for distribution to teachers in the elementary schools, also.

The Elementary Science Curriculum

Most of the studies published during the period covered by this review dealt with elementary science curriculums. Many, such as Challand (1958), Kuslan (1959b), and Bruns and Frazier (1957), assessed the scope and sequence of programs. Challand appraised instruction in Illinois by distributing questionnaires or checklists to determine how teachers selected areas of elementary science to teach. She found little co-operative planning among teachers and students in determining content, and the scope of a program seemed dictated primarily by the textbook used. In many cases, instruction in science is incidental to that in other areas, and in many schools is integrated with other areas. Challand found also that elementary science is taught as a series of "atomistic packages" rather than as a cohesive discipline.

Another aspect of the study dealt with the desirable time allotment for elementary science. School administrators and curriculum co-ordinators consider 2.7 hours a week "desirable." Teachers reported, however, that they devoted 1.9 hours in the primary grades and 2.4 hours in the upper grades to science instruction.

Bruns and Frazier (1957) similarly surveyed practices in 21 major cities of the United States (including Baltimore, Chicago, Cincinnati, Tulsa, and Oakland, California) as indicated in teachers' manuals, syllabuses, and study guides. They found no well-defined patterns of scope and sequence in elementary science teaching. About half the cities had a "spiral" approach which taught certain basic areas of science at an early level and repeated instruction in those areas every two or three years thereafter, presenting increasingly difficult concepts.

In some schools the "spiral" was organized on a K-2, 3-4, 5-6 plan; in others, on a K-3, 4-6 plan. In the analysis of study guides and course outlines no consistent pattern was found in the grade placement of science topics. Bruns and Frazier saw many cogent questions yet to be answered about the teaching of elementary science.

Kuslan's (1959b) study was designed to elicit information for the purpose of bettering the training of prospective elementary-school teachers. He surveyed the science programs in four schools utilized by New Haven State Teachers College in training prospective elementary teachers. He sought information as to (a) the kind of science taught in the training schools, (b) the science backgrounds of the teachers in the training schools, (c) the factors aiding or hindering instruction in the science program in the training schools, and (d) the strengths and weaknesses in science of the student teachers. The method employed was a questionnaire validated previously by a jury of experts.

An analysis of a 75-percent return revealed these findings: (a) In general, science is not taught as a separate subject, although definite science activities are included in the elementary program. These activities are usually spontaneous and based on student interest. (b) Teachers claimed more science background than they actually had. This finding was revealed by comparing the background professed by the teachers with their transcripts. (c) Major lacks hindering science instruction were material, audio-visual aids, books, special advisory services, and community resources. There was also difficulty in organizing field trips. (d) Plant and animal life were dealt with frequently at all grade levels, but machines and energy infrequently. (Emphasis on biological areas is supported by findings of other studies in other areas.) Teachers believed inservice programs utilizing members of the college science staff to be the most helpful method of improving elementary science instruction.

A question basic to the development of an elementary science curriculum is: What subject-matter topics should be included, and at what level(s) should they be presented? Many researchers have sought to answer this question, among them Nelson (1958, 1960), who was concerned specifically with the grade placement of concepts of light and sound. In one study (1958) she attempted to discover how children in the intermediate grades learn concepts and principles of light and sound; to determine whether socioeconomic background and IQ are related to their understandings; to determine whether differences in performance on tests are a function of sex; to determine whether performance is a function of grade level; and to answer other similar questions.

A total of 118 children in three schools, grades 4, 5, and 6, were given tests both before and after instruction in the subject-matter units. The tests included the *Otis Quick Scoring Mental Ability Test, Beta,* Form A, the *Oxendine Sound Test,* a multiple-choice word-classification test (words related to sound and light), and an object-classification test in the areas of light and sound.

Nelson did no actual classroom teaching, but in a special workshop she instructed the classroom teachers as to the implementation of the experimental design. After the teaching and testing, each child was interviewed to elicit his understanding of the concepts. Among important conclusions were the following: (a) the instruction produced an increment

in the understanding of the principles of light and sound; (b) a significant gain in achievement on the test on sound was noted, the gain being related to the grade level of the students; and (c) neither socioeconomic background nor sex was a significant factor in the observed gains.

Read (1958) reviewed research on grade placement of science topics. Such studies attempt to discover whether pupils can learn to apply vicariously, in a written test situation, some basic principles of physical science which are helpful in classifying their local present environment. The research also seeks to find out whether mental age and grade level are factors in this learning.

Read's review summarized 23 studies conducted at Boston University, all of which included pretesting, a multifaceted demonstration with oral exposition of one science principle demanding pupil concentration, and post-testing. Each involved students at two grade levels or more, and sought to determine whether the understandings of concepts by students were influenced by the maturity of the student. Read concluded that (a) intelligence is a factor in achievement; (b) grade level is important in the placement of science topics, since the upper two grades tested were consistently higher on the pretests; and (c) it is possible to teach science principles at a grade level lower than that at which they are currently taught.

Dubins (1959a), concerned with grade placement of science topics, analyzed 192 study guides and courses of study for science published 1940-52, to determine (a) the topics included, (b) the principles and the grade level at which they were presented, (c) the objectives of science instruction, (d) audio-visual aids suggested, (e) evaluative techniques recommended, (f) references listed for pupils and for teachers, and (g) the general organization of the guides. He found the same major areas of instruction appearing in most of the guides. In order of frequency, they were (a) the earth, (b) living things, (c) man's control of his surroundings, (d) energy, and (e) the heavens. Observing almost 500 other science areas listed in one or more of the guides, Dubins saw "much confusion as to what to teach" and believed that in many school systems the first essential step in building a science curriculum is neglected, namely, establishing objectives. Only 38 percent of the guides listed objectives.

Children's Learnings in Science

The prime objective of elementary science teaching is to help children acquire an understanding of, and an ability in, the topics and skills related to science. Thus, some consideration must be given to the questions: (a) How can science learning be assessed? (b) How can science learning be improved?

In an effort to develop a technique for evaluating science understandings, Young (1958) sought to determine the concepts of atomic energy

that children gained from out-of-school experience. The same eight items were submitted to 75 third-grade children by interview and to a group of sixth-grade children by questionnaires. Some were questions, such as "What are things made of?" "What are atoms?" and "What is a Geiger counter?" Others consisted of pictures to interpret. For example, students were asked to distinguish between pictures of a cumulo-nimbus cloud and the mushroom cloud of a nuclear detonation.

Responses, both oral and written, were scored: did not know, or had a misconception; had some information; had detailed information. Despite inclusion of examples, the exact nature of the rating scale is unclear. Among "significant" findings were that (a) at the third-grade level, boys scored consistently higher than girls; at the sixth-grade level, the difference was not so pronounced; (b) at least one-fourth of the eight- and nine-year-olds were ready to pursue further study of atomic energy; (c) both groups had many misconceptions about atomic energy; and (d) the impact of television, newspapers, and adult conversation on children's understanding of atomic energy was evident.

Jones (1959) attempted to measure the learnings of a group of first-grade children from a program of science experiment. The data consisted of a year's verbatim records (anecdotes) collected by a teacher from children's discussions that "resulted in experimentation." Jones concluded that (a) experimenting produced skills, concepts, and attitudes which contribute to development of desirable personal characteristics; (b) experiments contribute to the development of specific skills; and (c) experimenting helps develop an understanding of concepts of science at a more advanced level than that commonly used in first-grade textbooks.

Jones indicated obvious shortcomings of the study, namely, that a teacher could not record all comments and that "learnings" cannot be ascribed to the experimental program altogether. Obviously, some science learning takes place during ordinary classroom activity. The investigator's conclusion that further study is needed to test these hypotheses is, in the opinion of the reviewers, definitely warranted.

Apropos of Dubins' (1959a) belief that one weakness of science study guides is the failure to clarify objectives, Johnston (1961) undertook to determine how well the stated objectives of elementary-school science were achieved in a representative sampling of Minnesota schools. In addition she inquired, "What pupil, teacher, and teaching-situation factors contribute to the achievement of these objectives?"

Questionnaires were sent to 478 superintendents and to a proportionate stratified random sampling of 87 Minnesota fifth-grade teachers. Additional information was obtained from logs of science activities kept by some of the teachers, from intelligence-test scores, and from pretest and retest scores on science examinations administered to 87 fifth-grade classes.

Johnston found emphasis on science in elementary classrooms less than that given to social studies or reading, and more than that given to music

or art; the typical science class was 30 minutes long, and the average time spent on science per week was under two hours. Sixty percent of the schools had some purchased science equipment. Most of the teachers reported equal emphasis on biological and physical science, but their logs indicated a 3 to 1 ratio of biological topics to physical-science topics. Classroom activity emphasized textbook reading and discussion, and only limited use was made of experimental and laboratory activities, directed observation, and "research reading." It would appear that the objectives ordinarily accepted for elementary science are not being attained.

Among investigations as to *how* children learn science and what techniques can improve science learnings were those by Atkin (1958), Garone (1960), and Bohnhorst and Hosford (1960). Atkin's purpose was (a) to ascertain the nature of children's development in certain aspects of their abilities to formulate and suggest tests of hypotheses in science learning experiences and (b) to discover what relationship, if any, exists between the relative permissiveness of the classroom situation for problem-solving activities and the development of these abilities.

From one school system he selected "permissive" (three first-grade, four third-grade, and four sixth-grade) and "less permissive" (six first-grade, five third-grade, and three sixth-grade) classes. The relative permissiveness for problem solving was judged by the investigator, the principal, and the helping teacher. A class was qualified for the study if the judges agreed that it met the established criteria.

Classroom discussions during which attempts were made to elicit information concerning the "dynamics of children's hypothesizing" were recorded and analyzed by the investigator. The reliability of the investigator's analyses was checked by his listening to a sample of 20 percent of the original recordings three months after the initial analysis. Agreement between the two analyses was greater than 92 percent. The validity of the analyses was checked on a sample of recordings by the jury of three educators. Analyses of the jurors were no more than 4 percent at variance with the analyses of the investigator in any of the categories used.

The responses of the students were classified so as to answer two questions: (a) How do children formulate hypotheses? and (b) What types of procedures do they suggest for testing their hypotheses? Among the significant findings were that (a) children at upper levels use authority as the basis for hypotheses more frequently than children at lower levels; and (b) among the younger children, observation is used most frequently as the basis for hypotheses. A highly significant relationship between the classroom setting (permissive) and the bases for children's hypotheses was discovered. In a permissive atmosphere, children used authority as the basis for hypotheses less than did children in the less permissive atmosphere. Children in the permissive classrooms made "original" guesses more frequently.

Bohnhorst and Hosford (1960) sought to evaluate the merits of certain special procedures in teaching elementary science. Two groups of third-grade children in Atlanta, Georgia, regularly viewed television science programs once a week in the school auditorium. With the control group the classroom instruction that accompanied the television instruction was based chiefly on textbook units. With the experimental group the classroom instruction was based on questions raised by the children as a result of the TV lessons and other experiences with science. The questions were placed in a "wonder box" which was opened at certain times, the questions discussed and plans made for individuals and groups to answer them.

In order to measure gains in the achievements of both groups, the *National Achievement Elementary Science Test* was used as a pretest in October and as a post-test in May. In October there was no significant difference between the scores of the two groups. At the end of the program, the experimental group scored significantly higher than the control group. The researchers, allowing that many factors may have been responsible for the measured gain of the experimental group, imply that the "wonder box" approach was the significant factor.

Garone (1960), using techniques similar to those employed by Atkin (1958), studied 29 superior children aged 10-12 to observe their "science concept development" and gather information about their problem-solving ability. He made tape recordings and kept anecdotal records of their comments during group activities. Organizing data from recordings and records in terms of experiences and processes fundamental to children's science concept development, he concluded that appropriate problem-solving activities would improve children's concept development skills.

Under suitable conditions children will share their concepts and ideas with others, but they need guidance in separating fact from fiction. Sometimes a long period of time elapses between the original experiences and the development of concepts. Garone's vague description of techniques and findings casts doubt on the validity of his conclusions.

Improvement of Instruction in Elementary Science

Another category of studies dealt with techniques and methods that may be of value in improving instruction. Richardson (1960a, b) attempted to assess science teaching in the elementary schools of New Jersey and identify programs and activities representative of the best approaches. The appraisal was accomplished by means of a checklist of desirable practices, prepared by the investigator and validated by two juries of experts. Fifty-four typical lessons from kindergarten through grade 3 in 22 selected schools were observed, and "quality indexes" of the lessons were determined.

The indexes indicated that the quality of science instruction was low; many teachers were poorly trained in science; biological topics were

emphasized more than physical-science topics; limited use was made of activities designed to develop understanding and problem-solving abilities; and the least-used teaching tool was the experiment.

Richardson's observations led him to believe that (a) all elementary-school personnel should complete introductory laboratory-type courses in biology, chemistry, physics, and earth science, and a course in methods of elementary-school science; (b) these courses should include experiences in problem solving; (c) the teaching of elementary science should be centered around problem-solving situations, with sufficient permissiveness and freedom to provide for individual differences; (d) in the upper elementary grades science should be taught by science majors but should still emphasize problem solving and make frequent use of community resources; and (e) each classroom should have facilities for simple laboratory experiences.

Dubins (1959c), also concerned with improving elementary science instruction, devised an inquiry form and submitted it to many persons qualified to state what measures were being taken toward improvement. Responses indicated that (a) the larger the city the more likely it is to have a published course of study for and workshops in elementary science for teachers, and to employ a science consultant and science educators as special lecturers; (b) most states have colleges that conduct workshops in science for elementary teachers, although fewer than 10 percent of the states have agencies that publish materials for use by elementary teachers; (c) in many localities, science is not taught in the elementary schools; and (d) the activities of state departments of public instruction for improving elementary science are, at best, mediocre. Although Dubins' purpose was "to gather information concerning what is being done for the improvement of instruction in science in the elementary schools in the United States," his findings are more indicative of what is *not* being done.

Another study by Dubins (1959b) examined a method for rating an elementary science course. He applied five different scales to 29 courses. Values were then assigned to analogous components of the courses, and the sums of the ratings from the five scales were computed. A five-point scale was obtained by subtracting the lowest sum from the highest sum and dividing by five.

Dubins observed that to evaluate a course of study, an investigator must (a) determine factors to be considered, (b) arrange them in order of importance, (c) assign a maximum number of points to each factor, and (d) evaluate all guides on the basis of the same scale.

More research of higher quality is needed in this general category.

Teaching Aids for Elementary Science

Studying the use of television in science education, Reiner (1959) sought to determine the effectiveness of the "Science Corner" programs

in introducing and implementing the new elementary science course for kindergarten to grade 2 and grades 3-4 in New York City public schools. A total of 175 teachers from 47 schools participated.

At the close of the "Science Corner" series, the teachers were asked to indicate the degree to which each of the following outcomes was achieved: (a) stimulating pupil interest in the local environment; (b) increasing children's awareness of science; (c) making science part of a purposeful pattern in the classroom; (d) increasing the children's fund of scientific information; (e) increasing the teacher's information; and (f) using the series as a successful classroom aid.

The responses indicated that the telecast series was effective in improving these science programs. The teachers stated that (a) pupils' interest in the environment was stimulated; (b) pupils' interest in science was high during and following the telecasts; and (c) pupils' science information was increased. The programs assisted teachers in introducing the content of the new course, presented demonstrations suitable to the science classroom, and were valuable in suggesting activities for the science program.

Elementary science teachers became increasingly aware of the importance of reading level in selecting textbooks. Mallinson, Sturm, and Mallinson (1957) followed up a series of earlier studies to determine whether the reading difficulties of contemporary textbooks had been reduced. All texts published since the earlier study (mostly for high-school science and a few for the elementary level) were analyzed by the Flesch formula. In general, the recent textbooks were difficult; all but one of the elementary books had a reading level above the grade level for which they were designed. Publishers need to warn authors to pay greater attention to reading difficulty. However well organized a book may be, it is not likely to be of value if students cannot read it with sufficient ease to understand it.

In a second study, a sequel to the one just cited, Herrington and Mallinson (1958) tried to determine whether the measurements made with formulas of reading difficulty were more consistent than the estimates made by reading experts. Passages from science textbooks for grades 4 to 8 were analyzed by means of the Flesch, Lorge, and Dale-Chall formulas. The same 199 passages were sent to "reading experts" or "specialists in reading" in large cities for rating.

Measurements made with the formulas were more consistent than the estimates of the "experts." Among the experts there was not even general agreement with respect to levels of difficulty. In some cases their judgments varied by more than five grade levels. However, with 20 of the samples, measurements with the formulas indicated the same level of reading difficulty. Other comparisons of the results were always in favor of the formulas in terms of consistency. Hence, it would appear that teachers ought not to rely solely on their judgment of reading level when they examine textbooks, but rather to evaluate grade level of difficulty as

determined by a readability formula, and modify that with judgment as to content, organization, and interest level.

Teachers of Elementary Science

Emphasis on elementary science focused attention on the elementary classroom teacher. In meeting after meeting, one heard the statement that elementary teachers are reluctant to teach science. Victor (1960) undertook a study of factors which might be involved in the reluctance of elementary teachers to teach science. Possible factors hypothesized were (a) inadequate science backgrounds, (b) belief that one has to be a science expert to teach elementary science, (c) lack of familiarity with the objectives of elementary science instruction, (d) belief that "science teaching is a man's job," and (e) the "feeling of loss of classroom prestige, due to difficulty in answering questions about science."

A questionnaire designed to ascertain attitudes and opinions about these factors was submitted to teachers in grades 1 through 6 in one Illinois city. Of 116 questionnaires distributed, 106 were returned. Most respondents were experienced female teachers with less than two years of science in college, chiefly in biology. In the classroom they devoted one and three-fourths hours a week to science, and the science experiences were usually confined to three days. They reported adequate equipment, although some responses indicated infrequent use of it. Almost half the respondents reported that they used demonstrations only once a month or less often. The principal conclusion was that lack of familiarity with content and materials was a definite factor in the reluctance of elementary teachers to teach science. Loss of prestige because of inadequate knowledge was considered to be a related factor. Other factors were believed related to inadequate science background.

Piltz (1958) similarly sought "to find what, if any, relationships exist between aspirations of teachers and the difficulties they think they face" in teaching elementary science. He distributed a questionnaire to a 10-percent stratified random sample of Florida elementary teachers, interviewed a limited sampling, and made observations in certain teaching situations. A summary of the questionnaire responses revealed that in order of frequency, the areas in which problems of science teaching exist are physical facilities; methods and techniques of teaching; resources, materials, and equipment; field trips; content, subject matter, and area of experience; and library facilities. The problem of physical facilities was further verified during the interviews and observations.

Victor's and Piltz's studies indicate that teachers are concerned about their adequacies to teach science and recognize their difficulties in organizing an effective program of instruction. Some "experts" have advocated use of special teachers. A recent study of this question (Gibb and Matala,

1961) was designed to elicit answers to two questions: (a) Can science and mathematics each be more effectively taught by special science teachers than by the regular teacher? and (b) Are the effects the same for all children regardless of the ability of the child?

Four different kinds of public school systems (Cedar Rapids, Iowa; Lansing, Michigan; Versailles, Kentucky; and Washington, D.C.) were selected, and within them four fifth-grade and four sixth-grade classes with similar socioeconomic backgrounds. Two classes of each grade were taught science and mathematics by two special teachers; and the other two by the regular classroom teacher. At the beginning of the year, five tests were used to measure interest, general ability, and knowledge in social studies, science, and mathematics. The tests were again administered at the end of the year, and each teacher kept a log of daily activities related to the teaching of science and/or mathematics.

At the close of the first year, the following tentative conclusions were drawn: (a) fifth-grade science can be taught as effectively in self-contained classrooms as by special teachers; at sixth-grade level, special teachers are more effective than regular classroom teachers; (b) there was no evidence that either method was more satisfactory in rural or in urban systems; and (c) student interest fluctuated across the systems, but it was not possible to attribute these changes to the method used. Although the researchers emphasized that results of the second year may modify these conclusions, they asserted that their findings do not "support either type of organization as being superior for all school systems."

Summary

Although much past and present research in elementary science is of the survey type, more experimental and relationship studies are appearing. It is strongly recommended that researchers in elementary science devote future efforts to "how-to-do-it" studies, rather than to summaries of current practices and weaknesses. Attention should be given to *evaluating* the outcomes of elementary science programs. Within the span covered by this review, no published studies dealt with evaluation of student achievement.

Another area that needs research is what objectives of instruction are desirable and attainable. Researchers need to concentrate on identifying understandable, attainable goals and techniques by which classroom teachers can attain those goals. So far effort in this direction has resulted only in nebulous platitudes. Still another area requiring attention is that of preservice and inservice programs for teachers. Researchers could well seek to determine the optimal types of science training needed by elementary teachers and how best to provide this training. These are large orders, but they represent the areas most in need of extensive research effort.

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CHAPTER II

Mathematics in the Elementary School

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THE MARKED activity in this area is indicated by the length of this review and the number of reports covered. The material is organized under five major headings: Summaries and Bibliographies, General Factors Affecting Arithmetic Learning, Teaching for Specific Goals in Arithmetic, Research on Teaching Methods, Teacher Education, and Arithmetic Teaching in the United States and in Foreign Countries.

Summaries and Bibliographies

The period covered by this review produced, in addition to Hartung's (1957, 1958, 1959, 1960) annual annotated bibliography, two new types of reports. Weaver (1957, 1958, 1959, 1960b) examined research on arithmetic instruction from 1951 to 1956 and began an annual list of such studies. Weaver (1960c) also compiled a selected list of improvement projects related to elementary-school mathematics. Hunnicutt and Iverson (1958) reviewed research in arithmetic in connection with a report on research in the "three R's," and Glennon and Hunnicutt's (1958) review covered similar material. A summary of research in remedial arithmetic was prepared by Bernstein (1959).

In an extensive bibliography for the Twenty-Fifth Yearbook of the National Council of Teachers of Mathematics, Schaaf (1960) listed outstanding contributions in 16 divisions of arithmetic teaching. Weaver (1960a) listed selected summaries and critical discussions of research in elementary mathematics.

General Factors Affecting Arithmetic Learning

Some studies of arithmetic learning are reported under the headings of closely related topics. Sister Josephina (1959) found that fifth-grade pupils forgot in three months a significant amount of what had been learned, and attributed the loss to lack of drill and meaningful first learning. Klausmeier and Feldhusen (1959) found no difference in ability to retain arithmetic learning among three groups of pupils of varying intelligence but identical age (117 months). In an attempt to determine whether

100-percent automatic response for every pupil in a class is possible. Ulrich (1957) found that pupils varied in performance of two-digit multiplication (multiplier and multiplicand) from one day to the next. Collier (1959) reported the identification through study of eight major blocks to arithmetic understanding and recommended ways for removing these blocks. In a study concerned with the teachability of some of the basic concepts that underlie multiplication and division of common and decimal fractions, Brydegaard (1960) found that sixth-grade pupils can master these concepts when procedures which make for sharpness of the concepts precede practice.

Abilities and Attitudes

On the basis of an attitude inventory, Fedon (1958) found pronounced attitudes, both for and against arithmetic, developing as early as grade 3. Some essential aspects of arithmetic were enjoyed, but enjoyment did not necessarily indicate understanding. Feldhusen and Klausmeier (1959) found counting by 3's the highest level at which 117-months children of low intelligence could perform. Counting by 23's was the similar level for those of high intelligence. Among 269 sixth-grade pupils, Erickson (1958) found correlations of .72, .73, and .58 respectively between IQ and total arithmetic, IQ and arithmetic concepts, and IQ and problem solving. A correlation of .67 between arithmetic scores and reading comprehension scores was reported.

Keough (1960) reported a positive relationship between pupils' socioeconomic conditions and arithmetic achievement. On the other hand, Alexander (1960) found no significant difference in socioeconomic status, verbal fluency, or spatial visualization between high and low achievers in grade 7. Corle (1958) observed improvement in ability to estimate measures after fifth-grade instruction. Stright (1960), using a revised form of the *Dutton Attitude Scale*, found that, in general, pupils' attitudes toward arithmetic improve during the period from grade 3 through grade 6.

Number Concepts of Children

Gunderson and Gunderson (1959), repeating a 1939 study of number ideas of seven-year-old children, found many more similarities than differences. The 1959 children had better concepts of fractions but were not as capable as the 1939 children in addition and subtraction. Seven-year-olds were found to have a wide use for number knowledge. Davis, Carper, and Crigler (1959) reported that, although there are marked differences, four- and five-year-olds have considerable understanding of common measures.

Teaching for Specific Goals in Arithmetic

Fractions

Gunderson (1958) found that second-grade children, with word-problem settings and manipulative materials, could develop and use fraction ideas. Stephens and Dutton (1960) observed the common-denominator and inversion methods to be equally effective in developing skill in fraction division. They recommended that, since the common-denominator method gives more meaning to the process, both methods be taught. Aftreth (1958) concluded that systematic practice in identifying and correcting errors in addition and subtraction of fractions has no appreciable effect on achievement.

Jones (1960) surveyed development of vulgar fractions in American arithmetic books from 1719 to 1839. Struik (1959) discussed the historical evolution of decimal fractions.

Problem Solving

Chase (1960) found few academic skills and intellectual factors necessary to problem solving, the most important being ability to compute, ability to observe detail, and knowledge of fundamental concepts. A number of secondary variables are related—such as knowledge of generalizations which underlie the number system and ability to apply reading skills to a variety of purposes. Corle (1958) saw a high relationship between accuracy in problem solving and understanding, and between problem solving and confidence in one's own accuracy. He found that computational inaccuracy accounted for only 12 percent of the errors. On the basis of pupil performance in estimating quantities, Corle believed some pupils' difficulties due to an inadequate concept of the measures involved.

Mental Arithmetic

Although mental arithmetic is frequently mentioned in the literature, only six research studies bearing on the subject were reported. Analyzing exercises in six textbooks, Flournoy (1957) noted the need for more mental-arithmetic exercises and for improving their quality. In a later study Flournoy (1959c) found that 72 percent of the uses of arithmetic of children in grades 3, 4, 5, and 6 were of the non-pencil-and-paper type. Olander and Brown (1959) observed oral presentation of subtraction to be more difficult for pupils than flash-card presentation. Sister Josephina (1960), studying two techniques of presenting mental arithmetic problems in grade 5, found pupil performance better when the problem was read from the book and then looked at than after only oral presentation by the teacher. Wandt and Brown (1957) found three-

fourths of the nonoccupational uses of mathematics among a group of 147 teachers and students to be mental, about half of these situations calling for exact computation.

Research on Teaching Methods

Methods of Instruction

Research in method continued to be characterized by studies concerned with both broad and specific aspects of instruction. The broad study is illustrated by Lankford and Pattishall (1956), who found significant differences favoring use of procedures which encouraged pupils "to think out independently the basic operations in ability to add and subtract fractions." Eads (1957) listed use of developmental levels of learning and pupil participation in planning, conducting, and evaluating learning experiences as effective principles to guide action research. Shipp and Deer (1960) observed that achievement tends to increase as the amount of time devoted to development increases.

British teachers' use of colored rods (Cuisenaire-Gattegno) in teaching arithmetic was discussed by Howard (1957). Users were convinced that the method has value; that greatest benefit accrues to the best pupils; that some concepts can be developed most easily by this means; and that the approach holds promise as a supplement to current methods. Brownell (1960), observing practices and consulting with school officials in England and Scotland on the Cuisenaire-Gattegno and Stern approaches, observed that (a) these experimental programs are not extensive in England and Wales but are more used in Scotland; (b) the color approach does not eliminate counting as a substitute for addition; and (c) the experiences of British schools with the new approaches to arithmetic teaching have important implications for U.S. schools. These implications are that (a) we have underestimated the attention span of beginners; (b) we have underrated the readiness of beginners for systematic work in arithmetic; and (c) children in the lower grades can learn much more in arithmetic than they are now asked to learn.

Burns (1960), studying specific aspects of method, found that use of thought-provoking review study questions produced superior learning and that teachers favored use of these questions. Mazzei (1959) reported that, although estimating answers produced only slight gains in achievement, the procedure led to thoughtful analysis, with resulting better understanding. Kenney and Stockton (1958) found a method combining emphasis on drill and understanding more effective in teaching percentage than emphasis on either alone. Tredway (1959) reported that emphasis in instruction of seventh-grade pupils on the relationships between the elements of percent (usually named number, percent, and part) was more effective than the usual textbook presentation.

In a test of two methods (round up and a combination of round up and round down) of estimating the quotient, Flournoy (1959a) found that some pupils, especially low achievers, did not apply both rules in a test situation. On the basis of the results, the value of teaching two rules was questioned. Flournoy (1959b) also reported the caret method of placing the decimal point in decimal division superior to the subtraction method of placing the decimal point.

Evaluation

Continuing interest in new instruments for evaluating achievement in arithmetic, especially understanding, is indicated. Rappaport (1959), reviewing the literature on tests for understanding, concluded from it and from experimentation that to devise an objective test of understanding is both essential and possible. Experimental investigation of the relationship between computational-skills tests and meanings tests led Rappaport (1958) to believe computation a poor indicator of a pupil's grasp of meanings. Sax and Ottina (1958) constructed a test of mathematical meanings for comparing the achievement of children from "progressive" and from "conventional" schools. They found that the deviation of the differences favored the "progressive" school, but not all of the findings were statistically significant.

Individual Differences and Enrichment

How to adjust instruction to the abilities of pupils continued to attract investigators, whose interest appeared to shift from low performers to high performers. From tests and observation, Lewis and Plath (1959) were led to believe separation from the group and provision for intensive study of numerical operations a promising procedure for use with highly able children. Comparing performance of 11 ability-grouped classes with that of eight classes not grouped, Provus (1960) saw bright pupils profiting most from grouping. Holinger (1958) gave a case report of an advanced first-grade child who lacked ability in arithmetic. Shepard (1958) found study of the Pythagorean theorem a possible source of enrichment for fifth-grade pupils. To enrich the program in a one-year experiment, Townsend (1960) recommended use of advanced materials with pupils of superior ability.

The Casis School Faculty (1959) in Austin, Texas, exploring ways of meeting individual differences in arithmetic, reported no specific findings but summarized the techniques which seemed useful. Durrell (1959), trying to adapt instruction to individual differences, grouped pupils within classrooms for arithmetic instruction and fitted textbooks and materials to ability. Achievement improved significantly in grades 5 and 6; the improvement was greater in problem solving than in computation.

Grade 4 showed no improvement. Studying programs and records of schools chosen from the Educational Records Bureau Independent Schools list, Erhart (1960) observed much administrative effort being put into attempts to supply an arithmetic program suited to the academically talented. He saw more arithmetic material being offered to the talented and at an earlier age than to average pupils.

Materials of Instruction

Studies involving materials of instruction covered a wide range. Folsom (1960), from a study of the manuals accompanying arithmetic books, reported that teachers like suggested prebook instructional exercises. She recommended that texts and manuals be planned simultaneously, in contrast to present practice for fitting the manual to the text. Durr (1958) found workbooks helpful to learning. Studying the application of research findings to textbook production, Dooley (1960) concluded that recommendations in yearbooks of the National Society for the Study of Education and the National Council of Teachers of Mathematics were applied quickly.

Anderson (1957) found no significant effect on eighth-grade pupils' learning from use of visual-tactual devices in a unit on areas, volumes, and the Pythagorean relationships.

Jarolimek and Foster (1959), judging from fifth-grade pupils' performance involving quantitative concepts, found three widely used social studies books varying in difficulty. Repp (1960) observed considerable variation in the vocabulary levels of five third-grade arithmetic texts.

Stokes (1958) listed problems involving arithmetic that children encounter and their ways of solving them. He recommended that materials evolved from the problems indicated by 72,000 children be made the basis of the arithmetic curriculum for grades 1 through 8.

Television, Machine, and Film Teaching

Use of television, teaching machines, and films for teaching elementary mathematics was the subject of several investigations. Jacobs and Bollenbacher (1960) compared the achievement of three groups of seventh-grade pupils: (a) those partially taught by television, (b) those taught by the same teacher using conventional methods, and (c) those taught by a different teacher using conventional methods. With high-ability pupils, conventional teaching was superior; with average-ability pupils, television teaching was superior; with low-ability pupils, the difference in result between television and conventional teaching was negligible.

Using a multiple-choice method for automated teaching of areas of rectangles, Keislar (1959) found performance of the automated-teaching

group superior to that of a matched group which received no planned instruction.

Teacher Education

The great interest in elementary mathematics teaching has not produced corresponding interest in research in teacher preparation. Undoubtedly, more research in teacher training, influenced by the new emphasis on arithmetic, will soon appear. As background, the review of research in college mathematics and teacher education by Meserve and Schumaker (1957) should be helpful.

Observing the vocabularies of elementary mathematics terms of prospective teachers and the low relationship of this vocabulary knowledge to arithmetic achievement scores, Phillips (1960) contended that a testing program for elementary-school teachers should extend beyond a test of elementary arithmetic achievement. Arithmetic achievement alone would not guarantee knowledge of vocabulary.

Testing 450 experienced teachers led Bean (1959) to believe that teacher understanding of arithmetic increases with experience for 11 to 15 years. Waggoner (1958) found that prospective teachers made significant gains in mathematical competency in a course designed to aid students to understand the nature of arithmetic. Fulkerson (1960) found that prospective teachers' competence in arithmetic increased with years of preparation in high-school and college mathematics. Standlee and Popham (1958) reported that more than 75 percent of the elementary-school teachers in Indiana (93 percent of those graduating from large public institutions) have fewer than 10 hours of college mathematics credit.

From a questionnaire, Stipanowich (1957) found outstanding educators advocating two years of high-school mathematics as a requirement for admission to an elementary-teacher-training program; they also favored a proficiency test before enrollment in the required mathematics background courses and urged that subject-matter and methods courses be separate.

Barnes, Cruickshank, and Foster (1960) found 70 percent of "superior" fourth-grade teachers of arithmetic (principals' rating) without college credit in mathematics; 24 percent had one to six units of college mathematics. Corresponding percentages for "fair" teachers were 77 and 23 percent. Teachers rated "superior" by administrators tended to underrate their own ability; teachers rated "fair" tended to overrate their ability. Superior teachers had a positive attitude toward their high-school mathematics, and a large proportion of fair teachers reported a negative attitude.

The Committee on the Undergraduate Program in Mathematics (1960), under the chairmanship of Buck, recommended that two years of college

preparatory mathematics be a prerequisite to the program for training elementary-school teachers.

Arithmetic Teaching in the United States and in Foreign Countries

As indicated by the number of studies, comparison of arithmetic teaching in the United States and in foreign countries was a popular area of research. Buswell (1958), using an adapted form of a test from England, reported that English pupils made significantly higher scores than California pupils of the same chronological age. With the same materials and approximately the same conditions as those of the Buswell study, Bogut (1959) obtained in St. Paul, Minnesota, a mean score of 19.6. The mean for the comparable English school pupils was 29.6; for the comparable pupils in the Buswell study, 12.5. The relative differences of the means on the computational part (St. Paul 6.5, England 14.3, and California 4.3) and the problems part (13.1, 15.3, and 8.2) of the test are, according to Bogut, a reflection of the meaningful approach in teaching used in American schools.

Comparing arithmetic achievement of Iowa pupils and Dutch pupils, Kramer (1959), using a modified form (to fit the Netherlands conditions) of the *Iowa Basic Skills Test,* found significantly higher means for the Netherlands pupils, but indicated factors which make simple comparisons of means questionable. Dutch pupils complete their arithmetic study in six years, devoting 27 percent more time to the subject than Iowa pupils give to it in eight years. Forty percent of sixth-grade pupils in the Netherlands have repeated at least one grade; only 10 percent of Iowa eighth-grade pupils have repeated a grade. The top 10 percent of pupils finishing the study of arithmetic in Iowa achieve at the same level as those in the Netherlands, the Iowa pupils being two years older and the Netherlands pupils having spent 27 percent more time on study of the subject.

Kreismer (1958) observed performance of Glen Rock, New Jersey, fourth-grade to eighth-grade pupils to be higher on an Ontario arithmetic operations test than the performance of pupils in Ontario.

Using the same British test that Buswell used, Tracy (1959) reported, for white eighth-grade North Carolina pupils at the same stage (near completion) of arithmetic study as their British counterparts, a mean of 30.9, as against a British sixth-grade mean of 29.6 and the mean of 12.5 reported by Buswell.

Miller (1960) found less time being devoted to arithmetic in the United States than elsewhere. De Francis (1959) observed the content of Russian first-grade texts to be far more extensive than that of comparable American books, but failed to report that the Russian books are for eight-year-olds. The Russian books contain many work problems. In

another comparative study of textbooks, Schutter and Spreckelmeyer (1959) found the mathematical content of U.S. textbooks (especially in the lower grades) less than that of European.

Some of the difficulties in making comparisons can be deduced. If, for example, achievement of pupils is to be the criterion on which schools are compared, then time spent in study, it seems, should be considered. As pointed out by Kramer (1959) and Tracy (1959), European schools finish arithmetic study in six years; U.S. schools allot eight years. Comparison of the achievement of sixth-grade pupils in Europe with sixth-grade pupils in the United States is then not very meaningful. The same is true of a comparison of texts.

Chetverukhin (1959) reported the time alloted to arithmetic in the Soviet elementary grades (1-4) and intermediate grades (5-8) as 360 minutes a week. Beginning in grade 5, elementary mathematics is taught by special teachers. In 34 large U.S. school systems, Miller (1958) found the median daily arithmetic time varying from 23 minutes in grade 1 to 45 minutes in grade 6. In smaller cities the corresponding time varied from 30 to 47 minutes.

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CHAPTER III

Science in the Secondary School

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SECONDARY-SCHOOL science education has, in the past few years, received support to an extent heretofore unknown. New courses are being developed under ever more desirable circumstances. At the same time science-education research at the high-school level continues to be fragmentary and limited in scope. The review which follows is restricted to investigations considered sound in design and analysis which had both breadth of interest and more than local applicability.

The Status of Science Instruction

Three studies of the status of science instruction, national in scope, provided a description of science teaching, the teaching facilities available, and the requirements and recommendations of state departments of education. The National Education Association Research Division (1958) provided figures, more meaningful than those provided in earlier studies, which showed that of 1,250,000 high-school graduates in 1957, about 175,000 had taken four years of science and 480,000 had completed three years. More than half the schools were engaged in science curriculum review and revision before the first Russian satellite was successfully orbited. Less curriculum revision was being undertaken in the junior high schools than in senior high schools. The study concluded with the statement that secondary schools were doing a more comprehensive job in science instruction provisions and improvements than has been assumed in current discussions.

Obourn and others (1960) obtained data on the facilities and equipment related to science teaching. The questionnaire study involved a survey of the entire nation. Such factors as geographic location, size of school enrollment, and type of school were taken into consideration in presenting the data.

Martin (1960) collected state department of education requirements and recommendations pertaining to facilities and equipment for science and mathematics teaching. The report included specific recommendations for each of the states, with plans and drawings of facilities in many instances. The findings for elementary and secondary schools were summarized into tables for easy comparison.

Studies at the Junior-High-School Level

Curriculum

The junior high school has as yet seen no major programs of curriculum building comparable to those for the senior high with the new programs in biology, chemistry, and physics.

Özinőnű (1959) identified and built teaching units around concepts from mechanics, electricity and magnetism, and quantum mechanics. The units were taught over a period of 55 class sessions to a ninth-grade class with above-average intelligence. Instructional activities and suggestions ranging from field trips to suggested reading were designed and ordered to proceed from precept development through qualitative, then quantitative, concepts, to abstract concepts of phenomena. Achievement gains were significant at the 1-percent level. Özinőnű also found the correlation between IQ and concept pretest scores (.51) considerably higher than between IQ and general-science pretest scores (.01). Without indicating the basis for the statement, he concluded that pupil interests were broader and more varied as a consequence of this teaching. He also concluded that concepts can and should be identified, and can be learned if suitable learning conditions can be created.

Rosenberg (1957) dealt with the ability of selected eighth-grade pupils to locate relationships among the lever, wheel-axle, and/or pulley; to state these relationships numerically and verbally; and to relate the lever to the wheel-axle and the wheel-axle to the pulley both graphically and verbally. He developed a unique teaching method involving a series of flap-covered diagrams. Pupils had greater success in indicating numerical relationships than in verbalizing the relationships. They were more successful in indicating the relationship between the lever and the wheel-axle than they were in perceiving the relationships between the wheel-axle and the pulley. A suggestion of transfer was detected in the fact that 98 percent of the pupils who succeeded in indicating a numerical understanding of the lever were similarly successful with the wheel-axle. Fifty-five percent were able to relate these two simple machines graphically. This study appears to have considerable bearing on the teaching of science principles by pupil discovery and in suggesting a method for implementing this kind of instruction.

Methods and Organization for Teaching

A new dimension was investigated for the possible improvement of motion picture presentations. Schulman (1959) added introductory sequences to science instructional films in order to determine whether the nature of the sequence had any effect on immediate and delayed recall of factual materials presented in the film. He used a "positive" sequence

which showed the viewer a means to a pleasant goal he was already stimulated to achieve and contrasted it with a "negative" sequence which showed the viewer a means of avoiding an unpleasant situation. Pretests and IQ tests were administered at the start of the experiment. Retests were given immediately after viewing and again two weeks later. Scores were analyzed through the use of analysis of variance and *t*-tests.

Schulman noted that although learning took place regardless of the inclusion of positive or negative introductory sequences, the use of positive sequences resulted in greater immediate recall and negative sequences resulted in greater delayed recall. Boys learned more, in terms of immediate and delayed recall of facts, when the films had positive introductory sequences. No similar significant difference was found in girls' achievement. Irrespective of the nature of the introductory sequence for the films, when immediate recall was measured, "average" pupils profited most from seeing the films. However, their retention over a two-week period of what they had learned from the films was significantly less than that of either the "inferior" or "superior" groups.

The effectiveness of telecasts in helping ninth-grade pupils learn more science as well as predisposing them to further study in science was examined by Champa (1957). Three hundred pupils, boys and girls in equal numbers, were arranged into three groups: a conventionally taught group, a group taught the same content supplemented twice weekly by 15-minute telecasts, and a group taught the same course supplemented by a half hour of the motion picture films viewed each week by the television group. Neither the conventional nor the motion picture group had advantage of the resource people who appeared on television. Evaluation was carried out through pretesting and post-testing with a standardized general-science examination, and teacher-made unit and retention tests. All three groups made significant gains. It was not stated that significant differences existed among the groups. A year later a few more pupils from the television and motion picture groups continued to take science than from the conventional group. Science interests as indicated by the *Kuder Preference Record* and science-related activities were significantly greater for girls in the motion picture group than for girls in the conventional group.

The relationship of pupil achievement to the organizational pattern for teaching eighth-grade science was examined by Dameron (1959) in seven Middle West high schools. The organizational patterns included a core curriculum in which science, social studies, and English were taught in a three-hour time block in both grade 7 and grade 8, a two-semester eighth-grade course with no science in grade 7, and a one-semester science course in grades 7 and 8. Pretesting and post-testing of 1495 pupils showed the pupils' average to be at the 98th percentile on national norms. There was no significant difference in achievement of the pupils in any one of the organizational patterns when mean scores were compared through the use of analysis of variance and covariance with IQ and pretest scores held constant.

Dameron admitted not knowing how far other variables (such as teacher preparation and qualifications and teaching methods) might have influenced achievement. It would appear that the sample used was not truly representative of the typical school enrollments, thus limiting the applicability of the findings.

Achievement

McCutcheon (1957) sought to determine the relative achievement in science and mathematics at the eighth-grade level, using teacher-made examinations, in relation to school organization and enrollment and pupil ability as indicated by pretest and IQ scores. The study was well designed, involving a 4 by 4 block, using analysis of variance and covariance. More than 6000 pupils from a stratified random sample of 74 Minnesota public schools were tested. McCutcheon found statistically significant differences (1-percent level) in achievement in mathematics and science between schools; in science the difference was in favor of boys when pretest and IQ scores were held constant. Groups composed of the top, bottom, and middle 5 percent of the pupils, as determined by IQ, were compared in final achievement in both science and mathematics. Statistically significant differences among the three groups were found.

Norton (1959) sought to answer the question of whether achievement in ninth-grade general science was more closely related to study habits than to intelligence, reading ability, and aptitudes. Study habits were rated by both students and instructors. Achievement in science was measured by a teacher-made objective examination. Zero-order intercorrelations were calculated among test scores for achievement, *Iowa Silent Reading Test*, *Otis Quick Scoring Test*, and an average *Differential Aptitude Test* score, and students' and instructors' rating of study habits and their application; the multiple correlation between achievement and the six variables was also determined for each sex. Teacher ratings of study habits were not more effective than the other measures. In fact, they were less valuable than any other measure for predictive purposes. The average *Differential Aptitude Test* measure was the most significant achievement predictor for boys and girls considered together.

Oakes (1959), in a similar study involving gifted eighth-grade pupils, used a slightly different array of independent variables. The measure of achievement was the *Read General Science Test*, Form BM. The most efficacious battery of predictors of achievement, as included in a multiple-regression equation, included the mechanical and verbal reasoning scores of the *Differential Aptitude Test*, the mechanical-interest score of the *Kuder Preference Record*, and the *Read General Science Test*, Form AM score used as a measure of previous achievement.

Studies at the Senior-High-School Level

Biology: Curriculum and Teaching

Science teachers need to beware of changes prompted by external pressures. Change should come out of systematic examination of the objectives of science teaching. Curriculum workers and biology teachers will find Rosen's (1959) study helpful in understanding the historical factors leading to the move away from specialized courses in botany or zoology to the integrated course in biology.

In the high-school biology syllabus, it is important to include recent developments and unifying concepts. As part of the Science Manpower Project at Teachers College, Columbia University, Stone (1959) reviewed and evaluated current textbooks and courses of study for high-school biology. She found little attention to recent developments in biology and only minor attention to theories and unifying concepts.

Howard (1958) compared objectives of biology instruction in today's high schools with those of 40 and 80 years ago by means of an examination of textbooks. Present objectives and content of texts emphasize functional information and interrelationships among living things. Illustrations stimulate critical thinking. Texts of 40 and 80 years ago emphasized factual objectives and memorization of unrelated facts.

Tyrell (1958) asked 2000 members of the National Association of Biology Teachers to state what they believed to be the *most* important area and the *least* important area in biology. Their answers were to be used to construct a high-school biology achievement test. The areas suggested as most important were biological principles, conservation, essential life processes, and human physiology.

Newman (1957) compared the effectiveness of three teaching methods in high-school biology. The lecture-discussion method was used with outside-reading assignments, with textbook reading in class, and with no textbook or reading assignments in or out of class. Alternate forms of the *Nelson Biology Test* were administered as pretest and post-test. Three groups of 53, 56, and 52 pupils respectively were tested. There was a gain for each method of teaching, although none was significantly or statistically superior to the others. No one method was found to be superior for students who scored high on intelligence and reading comprehension. However, among students with low intelligence and reading comprehension, those taught with reading in class showed significant improvement over the others.

Chemistry: Curriculum and Teaching

During the last few years several investigators explored many procedures for teaching chemistry. Fonsworth (1957) attempted to achieve

reflective thinking by applying the methods of science to problems of daily life and human affairs. Both the teacher and the students co-operated in selecting problems and methods of solving them. Results were measured by the IQ, a critical thinking test, and standardized achievement examinations in chemistry. Fonsworth found gains under the reflective thinking approach significant with respect to (a) growth in mental ability, (b) the application of abilities required in critical thinking, and (c) the use of the scientific method in solving chemistry problems.

The nature of thinking in high-school chemistry study was investigated by Sister Ernestine Marie O'Connell (1958), who tested two hypotheses: (a) Inductive laboratory learning produces no higher achievement than does descriptive learning, as measured by the *Anderson Chemistry Test* and the *Cooperative Chemistry Test.* (b) Teaching which includes inductive laboratory learning produces no statistically significant differences in the understanding of chemical-equation balancing from deductive learning and traditional laboratory teaching. Six experimental and six control groups were used to test the first hypothesis. Thirty-two selected schools involving 56 classes and 40 teachers were used in testing the second hypothesis. The findings indicated that the two null hypotheses were rejected. Inductively taught classes showed superiority over the deductively taught classes in the year's work and in the unit on chemical-equation balancing.

Porter and Anderson (1959) concluded that ability to understand and apply the scientific method, with its associated attitudes, in chemical situations is perhaps more closely related to intelligence *per se* than any of the other parts of the chemistry test. Studying relationships of the specified abilities in chemistry to each other and to intelligence, they found the top intellectual group not always superior to the lower groups in achievement, and the middle group not always superior to the lower group. In terms of the total test, intellectually superior students achieved more than the average or lower groups. Except for the ability to understand and apply the scientific method with its associated attitudes, this hierarchy did not exist to the same degree for all the specified abilities in chemistry.

Pierce (1959) developed a modern course of study in high-school chemistry by means of review and evaluation of existing courses and textbooks. Proposals for the new course were submitted to a group of experts for judgment.

The method of performing experiments in high-school chemistry-laboratory manuals versus pupil-devised methods of solving the same problem was investigated by Mark (1958) in 12 classes in six schools. Measurement of acquisition of factual information and the ability to interpret chemical knowledge was accomplished through a standardized chemistry examination after a set of 10 experiments had been performed. A standardized chemistry aptitude examination was given as a pretest at the beginning of the second semester. Although the groups started not differing significantly and did equally well on the factual examination,

the experimental group was significantly (3-percent level) superior in ability to interpret chemical knowledge.

Physics and Physical Science: Curriculum and Teaching

Garside (1959) compared the effectiveness of two methods of instruction in high-school physics, as measured by levels of achievement, with students of high and low intelligence. A total of 690 students, representing 60 schools, were randomly divided into 30 traditional and 30 Harvey White physics films groups. Students were put into upper and lower (27 percent) ability groups. Regardless of method of instruction, the achievement of highly intelligent students was significantly higher than the achievement of students of low intelligence. When equated for intelligence, by means of covariance, there was no significant difference in retention between students of high and those of low intelligence. There was no significant difference in achievement between film and traditional groups; however, retention was higher for traditional groups.

Hubbard (1958) attempted to determine the effect of three teaching methods on achievement in a senior-high-school physics course. One group was taught by television only, another group by television supplemented by a physics teacher, and the third by the same teacher using conventional classroom techniques. No statistically significant superiority of any of the teaching methods was found, and no one of the methods worked better for any one ability level.

Engelhart and others (1958), evaluating the use of television in high-school physics instruction in Chicago, found that students with an IQ above 120 and those with an IQ below 100 apparently profited more from usual instruction than from television instruction. They believed teacher guidance and stimulation are needed by both groups.

Wise (1957) sought to determine whether courses in high-school physics or junior-college physical-science surveys increase pupils' qualitative understanding of physics principles beyond that acquired in junior-high-school general science. His tests, covering 24 principles of heat, were given to 1576 students from 23 states enrolled in 14 junior high schools and 15 senior high schools, and to freshmen and sophomores from 11 colleges. He found that (a) although pupils who have taken general science may expect that a physics course will increase qualitative understandings, a further increase will not accompany a college survey of physical science; (b) students who have taken both general science and physics may not expect a physical-science survey course in college to add materially to their understanding; and (c) a college survey course in physical science is no more effective than general science in developing qualitative understanding of certain principles. The study was concerned with a pertinent question. Unfortunately, there is no reason to suppose that the students and groups under test were from the same population.

How the experiment would have turned out if they had been, if other subject areas had been under consideration, or if quantitative understandings even at minimal mathematical levels had been measured are questions which merit further investigation.

O'Connor (1959) sought to describe and analyze laboratory problem-solving processes of high-school physics students. Although his groups were small (four groups of five each, selected on the basis of rank on ACE-Q scores and IQ ratings) and his findings tentative, his technique of checking steps toward solution of laboratory problems by direct observation and taped recordings of students "thinking aloud" is of interest. He found that pupils of high ability solved more problems than those of lesser ability, although problem solvers were not restricted to any ability group. Those who solved one problem did not necessarily solve others. There were no common patterns of solution or failure to find a solution among the problems, ability groups, or all students. O'Connor believed mental ability and quantitative conceptualizing were not sufficient bases for the selection of potential scientists.

Aptitudes, Interests, and Attitudes

A determination of the relationships between growth of interest and achievement of high-school science students and science-teacher attitudes, preparation, and experience was made by Taylor (1957). Standardized tests, such as the *Minnesota Teacher Attitude Inventory*, the *California Occupational Interest Inventory*, and science sections from the *Essential High School Content Battery*, were used. When considered singly, teachers' attitudes, semester hours of professional education, semester hours of science, and years of teaching experience do not have a positive correlation with student interest or achievement. Significant differences were reported in growth of interest between students who worked with full-time science teachers and those who worked with part-time teachers. No significant difference in achievement for such groups was reported.

Henderson (1957) investigated the interest in physiology of secondary-school pupils, parents, and physiology teachers. A checklist of physiology topics was evaluated by 999 students, 181 teachers, 97 parents, and 14 physicians. The findings indicated that parents and teachers were good judges of pupil interests, but physicians were not. Parents felt sex education was part of a school's responsibility.

Blanc (1958), studying pupil interests in biology, submitted a questionnaire of 92 topics to 60 boys and 60 girls from 10 tenth-grade and eleventh-grade biology classes. The findings indicated that emphasis given topics in textbooks and expressed interest of pupils had little correlation. It was also noted that the higher the first-semester grade, the greater the number of expressed interests in topics.

One of the conclusions reached by Allen (1959) in his investigation of attitudes of certain high-school seniors toward science and scientific

careers was that students do not have a clear-cut understanding of the nature of science and scientific work.

Stoker (1957) surveyed the aptitude and attitudes of high-school youth toward science and scientists and the relationships of these factors to each other and to the personal traits of youth. Among 2500 pupils in grades 10 through 12, a favorable attitude toward science and a social institution was generally expressed. A significant relationship was reported between aptitude and attitude toward scientists as people. Attitudes toward science as an institution and as a vocation and attitudes toward scientists were closely related to students' grades in science and their socioeconomic status.

A study by Behnke (1959) was based on replies from 621 high-school science teachers and 70 scientists. There was disagreement between the groups on 50 tested statements pertaining to the nature of science and scientists in society.

Using two examinations, one to measure the accuracy of one's perception of a scientist and of science and another to measure attitudes toward science and scientists, Belt (1959) tested 516 college-bound seniors from 12 New Jersey high schools and found a generally favorable attitude. Belt was disposed to discount previously publicized studies which expressed concern over the supply of scientists. Perhaps the greatest contribution of the study lies in the nature of the factual-perceptual test used in determining the image the high-school student has of science and of workers in this field.

Business and industry became increasingly involved in the improvement of science instruction. Sund (1959) examined business-industry suggestions made between 1949 and 1958 pertaining to objectives and philosophy, curriculum modification and teaching practices, recommendations for education of the gifted and for vocational and technical training, and teacher training and accrediting. He found many of these suggestions implemented by laboratory exercises, guidance materials, science fairs, assembly programs, and summer employment of teachers and high-school students.

Roper (1956) examined utilization of industry-sponsored instructional materials by Colorado high-school chemistry teachers and found that 96 percent of the teachers used such materials. He listed their reasons for using these materials and the order of their preference for them. Roper wisely suggested careful examination of the criteria by which these instructional materials are prepared.

Summary

Studies selected for review in this chapter were in great measure assembled by the U.S. Office of Education in its regular search for investigations related to science education. Some abstracting had already been

done by members of the Committee for the Review of Research of the National Association for Research in Science Teaching.

An examination of the bibliography will show that about two-thirds of the investigations have not yet been made available to other researchers and classroom teachers, their only publication being in *Dissertation Abstracts*. Moreover, the nature of the study and its findings are often so poorly reported there as to erroneously suggest that the study be examined no further.

The trends of greatest importance lie in the most recent research efforts in curriculum development. The team approach to course-of-study building may prove exceptionally effective. By the time the next issue of the REVIEW OF EDUCATIONAL RESEARCH devoted to science and mathematics is published, a report on the new courses in biology, chemistry, and physics could be available. These programs deserve a thorough evaluation which should answer such questions as what groups the courses are most effective for, as well as the level of achievement attained. Now lacking are studies relating to measurement of achievement or change beyond the level of factual information. Perhaps these measures will be included as part of the evaluation scheme associated with the new curriculums.

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CHAPTER IV

Mathematics in the Secondary School

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DURING the period 1957-1960, a time of ferment in mathematics education, a variety of experiments with new curriculums were conducted at local, state, and national levels. Evaluation of programs is a project for the immediate future. In designing and implementing new curriculums and new approaches, it is important that answers from research be used.

This chapter includes descriptions of experimental curriculums, of the current status of teaching in secondary mathematics, and of controlled experimental studies.

Current Practices and Trends in Mathematics Curriculums

Shetler (1958), by questionnaire, surveyed aims, curriculum, methods, and evaluation in the teaching of mathematics to determine how closely they agreed with research results and proposals. Replies from a 10-percent random sample of secondary schools in 20 states showed disagreement between expert opinion and practices in classroom methods and evaluation. Many teachers reported inadequate equipment and poor library facilities. The teachers who consistently follow recommended practices are those who spend most of the school day teaching mathematics, and those who have professional assistance in teaching. In a related study Diebel (1959) considered the influence of the evaluative criteria of the Co-operative Study of Secondary School Standards in 57 Oregon schools evaluated during the seven-year period 1950-57. This study indicates that the recommendations resulting from these evaluations are sporadically implemented.

One way to study the mathematics curriculum is to analyze textbooks. Izzo (1957) analyzed 627 secondary mathematics texts to determine trends in the use of graphical material. He found increased attention to graphing, especially in connection with locus and analytic geometry in plane-geometry texts. Similarly, Rajaratnam (1957) studied 10 elementary-algebra texts to relate the development of the concepts of variable, function, equation, and equality with the work of mathematicians and logicians. She observed new ideas mixed with outworn and erroneous ideas and terminology. Wilson (1959), examining geometry texts published before 1900, saw authors generally competent mathematically, but not very familiar with good teaching techniques and the learning process.

Wales's (1958) appraisal of texts for purposes of building a course of study was a typical misuse of textbook analysis. From 20 commonly used general-mathematics texts she compiled a list of topics and submitted them

to a selected panel of educators for ranking. On the basis of this appraisal, a recommended program for general mathematics was formulated.

One method of evaluating the effectiveness of a curriculum is to consider its contribution to success in college. Such an approach was used by Knights (1957), who analyzed a test given to entering college freshmen to determine their preparation for analytic geometry. Using these scores as predictors of success in analytic geometry, Knights showed that students need more skill in problem solving, more experience in applying learning, and more understanding of definitions, relationships, and symbols to be successful in analytic geometry.

A first step in a local curriculum reorganization is determination of the current status. In this kind of study, Bruns and Frazier (1957), surveying the variety of experimental programs in operation in Houston schools, found a fairly uniform sequence of algebra and geometry through grade 10 but considerable variation in including topics from analytic geometry and calculus in the upper grades. An interesting new course described was a laboratory geometry course for non-college-bound students.

Evaluating the Content of Mathematics Courses

A variety of new content is being brought into the mathematics curriculum, and the contributions of new topics need to be evaluated as well as those of traditional topics. We have little evidence with which to defend the old or the new. For example, it has been proposed that probability and statistical inference be a possible semester course in grade 12. The achievement of apt high-school juniors and seniors in such a course was studied by Bridges (1959). The experimental class of 19 members obtained significantly higher scores on the post-test as compared to the pretest and as compared to a control group of tenth-graders.

Another curriculum recommendation frequently made is that courses should be functional. Results of an investigation by Bush (1959) of two groups of students at one high school after two years of study do not favor a functional approach. The students with two years of formal mathematics were superior to the two-year functional mathematics students in every category tested. The technique of covariance was used to hold ability factors constant.

The success of curriculum proposals depends greatly on the attitudes of teachers toward the new ideas and their competence to teach them. Spillane (1959) studied the attitudes of Pennsylvania mathematics teachers toward the inclusion of analytic geometry, calculus, and statistics in the high-school program, and considered the teachers' competence to teach these subjects. On the basis of a 76-percent return of questionnaires to 500 randomly selected teachers, he found that teachers favor the inclusion of these topics in high school and feel generally competent to teach these subjects. As would be expected, younger teachers and those who felt competent to teach the subjects were more favorably inclined toward them. Similarly, Leissa

and Fisher (1960) surveyed the attitudes of engineers and college and high-school mathematics teachers toward the recommendations of the Commission on Mathematics of the College Entrance Examination Board. This group was highly favorable toward the recommended changes, being much in favor of including inequalities, sets, vectors, and probability. The group was not so favorably inclined toward including calculus, field theory, group theory, or statistics.

Another frequent curriculum proposal is to eliminate solid geometry as a separate course and include the concepts of three-dimensional space in tenth-grade geometry. To resolve the problem of what topics should compose tenth-grade geometry, Small (1959) submitted a list of 109 solid-geometry concepts to 50 mathematics teachers. Topics approved on 75 percent of 31 returned questionnaires included line perpendicular to a plane, lines parallel to a plane, loci, perpendicular planes, polyhedral angles, area and volume of prisms, cylinders, pyramids, cones, spheres, distances, angles, and areas on a sphere. Topics to be omitted included spherical triangles and congruence of prisms.

The number of experimental mathematics curriculums continues to grow, and projects that have been under way some time continue experimentation. The content and operation of several programs were described by Allen (1958), Brumfiel, Eicholz, and Shanks (1960), Davis (1960), and Keedy (1959b). No experimental project has reported data adequate to permit evaluation of its effectiveness.

The evaluation of a new curriculum will not be easy. A conference sponsored by the American Association for the Advancement of Science, the American Association of School Administrators, and the Council of Chief State School Officers was reported by Hull and others (1958). Its purposes were (a) to develop guidelines for program appraisal and direction in the teaching of mathematics and the sciences, and (b) to evaluate proposals being made for changes in school programs. The report will be found useful by anyone evaluating new curriculums. Putnam and Frazier (1960) compiled an annotated bibliography of state curriculum guides.

Attitudes, Concept Formation, and Understanding in Mathematics

Experimental studies, although few in number, showed concern for the significance of attitudes, the nature of understanding, and the formation of concepts. The significance of maturity and other variables in relation to an understanding of the limit concept was studied by L. T. Smith (1959). Among 578 students in grades 7 through 12, some classes were given three hours of special instruction in limits, other classes equated in mental age were not. Data were collected on a limits test, chronological age, mental age, and grade-point averages in mathematics. Findings showed experience to be important; significant gains in conceptualizing limit occurred at all

levels; chronological age is not a related variable; and mental age is positively correlated with limits test scores.

Troxel (1959) examined relationships within measures of reading eighth-grade expository mathematical materials, and between such measures and intelligence, arithmetic achievement, and general reading ability. He also studied difficulty and interest in relation to purpose as well as reading skills. Based on data from 45 students, sample conclusions were (a) reading purpose influences reading speed; (b) general reading ability is related to speed of reading expository mathematical material; and (c) difficulty is influenced by purposes. Johnson (1957b) analyzed readability of 25 samples of 100 words from each of 18 mathematics texts and proposed use of the modified Flesch formula for determining readability.

Poffenberger and Norton (1959) questioned 390 college freshmen to determine factors relating to attitudes toward mathematics. Factors having the greatest influence on attitude were previous teachers and parental expectations and attitudes toward mathematics. Renner (1957) tested functional competence among 237 Iowa high-school seniors who had taken one year of algebra or general mathematics. Using covariance to control initial difference on the *Iowa Tests of Educational Development,* he found a significant difference in favor of the algebra group over the general mathematics group. E. M. J. Ferguson (1957) developed an observational instrument for describing the algebra classroom in relation to selected aims such as (a) ability to think, (b) appreciation of mathematics, and (c) attitude of curiosity and initiative.

Approaches and Techniques in Teaching Mathematics

Studies of approach and technique emphasized individual differences, the use of visual materials, application, and specialized ways of teaching particular content. Zoll (1957) investigated the relative merits of varying amounts of application in plane geometry. Each of three teachers taught both experimental and control classes equated for intelligence, geometric aptitude, arithmetic and algebraic competency in one high school. Analysis-of-variance techniques showed no significant differences between classes with varying amounts of application and control classes nor among experimental classes in regard to ability to solve "originals," knowledge of facts and principles, or ability to apply facts and principles in practical problems. Ability to apply geometric facts and principles seemed to be associated with individual males of good ability and mathematical competence. With limited statistical and experimental controls, Miller (1959) compared a single-equation approach to solving verbal elementary-algebra problems with a combination of guessing specific solutions and a subsequent multi-equation approach. Thirteen classes split between the methods in one high school were used.

Shoemaker (1957) reviewed the effectiveness of teaching principles of mathematics and science in Ohio public-school trade and industrial pro-

grams and found the current plan ineffective. According to Mazzei (1959), teaching estimation to ninth-grade and tenth-grade students did not help significantly to reduce errors. Kenney and Stockton (1958) equated three groups of seventh-graders (with more than 100 in each group) and compared three approaches to teaching percentage: (a) drill emphasis, (b) emphasis on understanding and reasoning, and (c) a combination of the first two. Using a self-designed test after 19 days, they found progress in the upper three-quarters of all classes, and inconclusive evidence suggesting possible advantages for the composite and understanding approaches.

Among three heterogeneous interest groups totaling 79 plane-geometry students, Griff (1957) observed the effect of one-level and three-level assignments varied quarterly through the year. Using a test of functional competence and class quizzes, he found students doing more and better work in a one-level approach. The analysis and design were limited. Hines (1957) reported a limited study of the effect of homework on achievement in plane geometry. Although the matched groups were of restricted equivalence, achievement differences seemed to favor students doing out-of-class work, particularly on cumulative review tests as opposed to unit tests.

Crosby and Fremont (1960) found that small groups in algebra, with testing as appropriate, and freedom of topic choice, provided a better learning climate and effective opportunity for achievement. Although experimental and control groups were used, the study tended to be descriptive. An informal study, without controls, by Ivie, Fowler, and Graham (1958), indicated that use of small groups in algebra, geometry, and business mathematics provides a good learning situation. However, superior students showed limited desire to progress, and some students felt the need for class activities. Ilioff (1957) investigated the effect of systematic home-school co-operation on the achievement of eighth-grade students. Increased parental understanding had a consistently positive effect on pupil achievement.

Studies of Association and Prediction in Mathematics

Studies dealt with associations among mathematics achievement, school size, student ability and sex, teacher attitudes, curricular choices, and school policies. McCutcheon (1957) analyzed achievement in eighth-grade mathematics (and science) in relation to school organization, enrollment, and pupil-teacher factors in Minnesota public schools. A stratified random sample of 85 schools was used. Pretests and post-tests in mathematics, designed by the experimenter, and an intelligence test were administered. A total of 378 teachers answered questionnaires and 6471 students participated. Analysis-of-variance and covariance techniques led to such findings as the following: (a) there were no sex differences in final achievement with adjustments for initial differences; (b) girls scored higher on the pretests, post-tests, and intelligence tests; and (c) significant differences in achieve-

ment among the upper, middle, and lower 5 percent in intelligence were noted.

Pruett (1960) studied mathematics and science achievement of 44,649 ninth-grade pupils in 618 Indiana private and public schools. Girls did better than boys in mathematics, and the better mathematics students were found in schools with large enrollments.

Using 29 teachers of first-year algebra and 1643 pupils in 13 schools in a large midwestern city, McCardle (1959) related scores on the *Minnesota Teacher Attitude Inventory* (MTAI) to pupil achievement. He found pupils with teachers having high MTAI ratings profited most in quantitative thinking and functional competence; teacher attitudes were not significantly related to algebra achievement.

McKinley (1960) sought a relationship between achievement in a twelfth-grade probability and statistics unit and intelligence, reading comprehension, previous mathematics achievement, and previous mathematics experience. The study extended for only 13 class periods with 10 classes in nine schools. A maximum multiple-correlation coefficient of .68 was found with achievement and three intelligence factors, reading comprehension, and previous achievement in mathematics. McKinley believed such a unit desirable for college preparatory students and that aptitude for such work could be measured to a significant degree. Dinkel (1959) found a multiple correlation of .86 between algebra achievement and a series of seventh-grade and eighth-grade predictive variables, including previous grades, intelligence, and prognostic and achievement tests.

In an analysis of Wisconsin school policies as related to students' choice of high-school mathematics courses, Parkinson (1959) observed that (a) schools with college preparatory tracks enrolled a larger proportion of students in algebra at the ninth-grade level than those without; other schools enrolled larger proportions in grades 10 through 12; (b) 57.2 percent of the schools had college preparatory tracks and 70 percent of these required at least four semesters of mathematics for college preparatory students; (c) mathematics achievement, teacher reports, and IQ scores were influential in mathematics guidance; and (d) students indicated the importance of out-of-school factors, particularly parents, in the choice of mathematics courses. Stone (1959) saw an increase in enrollment in elective mathematics and science as possibly related to students' reaction toward teachers in introductory courses.

Secondary Enrollment, Teacher Characteristics and Preparation

Studies pertaining to enrollment and teacher factors include broad national studies, state-wide investigations, and proposed training programs. The most critical problem was the lack of properly trained teachers.

The National Education Association Research Division (1958) surveyed enrollment, curriculum revision, and facilities for mathematics and science

in U.S. secondary schools. Of 1957 high-school graduates, 14.4 percent had four or more years of mathematics; 22.9 percent, three years; 35.2 percent, two years; 25.6 percent, one year; and 1.9 percent, none. Principals tended to select teachers on the basis of skill in instructional methods rather than subject-matter preparation. Curriculum revision was reported in about half the schools. Facilities were seen as lagging. The large comprehensive high school was singled out for its contribution to preparation in mathematics, teacher qualification, curriculum, and facilities. Maul (1958) reported on teacher supply and demand in mathematics and science. The supply of candidates for high-school mathematics teaching decreased each year over a five-year period; one out of every three newly qualified persons did not teach. Turnover was great in what was described as an improved but still critical situation.

Teaching load and qualifications were summarized by Brown (1960). Mathematics enrollment in grades 9 through 12 was 4.4 million in 1956 and 4.5 million in 1960. About 100,000 seniors were unable to get advanced mathematics in small high schools. In 1957 about 43 percent of schools had curriculum studies in progress. In that same year secondary teachers averaged 23 hours preparation in mathematics; 7.1 percent had no mathematics; one-third were mathematics majors; and one-third had the master's degree but not usually in mathematics. Ahrendt (1958) believed that student enrollment and interest in mathematics were greater than generally claimed but that the shortage of adequately trained mathematics teachers was more critical than generally realized.

Torrance (1958) analyzed the extent of change in Minnesota mathematics and science teaching, using a 50-percent random sample of public secondary-school principals and superintendents. Four-fifths reported recent or pending decisions to improve their programs. Summer institutes and training programs were strongly supported. Finding and retaining qualified teachers was a major problem. Lohela (1958) studied enrollment characteristics and teacher preparation in Michigan secondary-school mathematics. Enrollment in mathematics decreased from 1925 to 1950 but has increased since. Nonpublic schools in Michigan enrolled a higher proportion of students in mathematics than public schools. Large schools had better prepared and more experienced teachers than smaller schools. Enrollment in mathematics dropped off rapidly for each succeeding grade, especially among girls. Teacher questionnaires revealed interest in practical application, realistic student teaching, college topics geared to the secondary school, preparation for dealing with individual differences, and instruction in motivation and class management.

Small (1957) sent a 52-item questionnaire to 1465 members of the National Council of Teachers of Mathematics to discover recommended aspects of a fifth year of preparation for mathematics teachers. Responses proposed 50 percent mathematics and not more than 25 percent professional education, with some work in research, advanced teaching, and cultural areas. Topics of interest were number theory, mathematics history,

mathematical statistics, modern algebra and geometry, theory of equations, mathematics of finance, adolescent growth and development, and measurement. Jorgensen (1958) outlined characteristics and advantages of an inservice institute.

Nelson (1959) received 100 usable questionnaires from 154 Nebraska secondary mathematics teachers designated as superior or above average by their administrators. Classes in 46 schools were visited and 2188 students were queried. These capable teachers entered the profession because they liked mathematics, selected their careers in college, participated in professional growth activities, taught upper-level courses, used a wide variety of methods, and were concerned about improving their teaching. The students of these teachers praised their explanations, helpfulness, and personalities.

Programs for the Gifted Student in Mathematics

Although much space was devoted to special programs for the gifted, few studies evaluated their effectiveness. Long (1957) examined an enrichment program in four classes of 98 randomly selected students. In two experimental classes talented students served as group leaders, presented new topics and materials, gave special reports and projects, and participated in contests. Activities for all of the experimental group included weekly review, extra-credit problems on the tests, and special projects. Both the control and the experimental groups received the same basic instruction from the same teacher and the same topics, assignments, and tests. On two achievement tests and an attitude inventory both the talented and the nontalented in the experimental group surpassed the control group in both achievement and attitude. As this study was carefully designed, used appropriate statistical tools, was extended over a school year, and applied principles of randomization and controls, considerable confidence can be placed in the implication of the contributions of an enrichment program.

Wells (1958) reported an informal experiment with a modified curriculum for capable students in one eighth-grade algebra class. Achievement of the 25 high-ability eighth-graders was comparable to that of ninth-graders completing a similar course. The former achieved as well as or better than the ninth-grade control group.

One of the problems in setting up a program is identification of superior students. Cherry (1958) selected 90 eighth-grade students out of 1600 on the basis of an aptitude test, an achievement test, a reading test, an intelligence test, and teachers' recommendations. Although this method was accepted by students and parents, Cherry urged continued study of individuals and flexibility of assignment. In a similar study, M. B. Jones (1959) found that Maryland schools use teacher recommendations, previous achievement records, intelligence test scores, and achievement test scores

to select the rapid learners. Over 90 percent of the participating schools reported the practice of ability grouping. Almost 60 percent provided special courses for their high-ability students.

Various programs have been advocated. Devine (1960) described a seminar to provide an accelerated program for gifted senior-high-school students, and Elder (1957) described a seminar to provide an enriched program for gifted junior-high students. Summer seminars supported by National Science Foundation funds with emphasis on topics from contemporary mathematics were described by Nichols (1960), M. L. Ferguson (1960), and Nielsen and Gohman (1959). Ferguson's findings from a state-wide summer program at eight centers in Tennessee indicated significant gains in subject-matter achievement by the experimental group, but no significant gains in ability to use knowledge for problem solving.

The national contest sponsored by the Mathematical Association of America and the Society of Actuaries was described by Fagerstrom and Lloyd (1958). The test used in this contest emphasized mathematical insight rather than isolated facts or skills. Pruitt (1960) and Keaveny (1959) described programs for grades 8 through 12 which are essentially acceleration programs with content similar to that of traditional courses in algebra and geometry. Elementary algebra is taught in grade 8 and intermediate algebra in grade 9. Plane and solid geometry and trigonometry are completed in grade 11 so that an advanced course such as mathematical analysis can be given in grade 12.

Teaching Mathematics via Television

Even though interest in and support for educational television have increased in recent years, relatively few efforts have been made to use television to teach mathematics. Wells (1959) compared the effectiveness of television-correspondence study of first-year algebra with that of direct teaching. Students in 11 small Nebraska high schools apparently achieved as well with television-correspondence instruction as with direct instruction. In another experimental study involving three classes in each of nine schools, Jacobs and Bollenbacher (1960) compared the effectiveness of televised lessons in seventh-grade mathematics with the results of conventional instruction. The year-long experiment used 20 minutes of live telecasts three days a week followed by 30 minutes of discussion. Care was taken to insure randomness, replication, control of variables, acceptable evaluation instruments, and proper statistical tools. The television method was found to be superior for the average student, but the conventional approach proved better for superior students. Other television projects are described by Berger (1958) and Andrews (1960). Extensive experimentation at different levels with valid evaluation of all objectives needs to be made before we can know the extent of television's contribution to mathematics teaching.

Facilities and Equipment for the Mathematics Classroom

The National Defense Education Act has provided funds for improved facilities and equipment, and several surveys have been conducted to determine needs. The U.S. Office of Education study by Obourn and others (1960) surveyed with a questionnaire a random sample of 1207 high schools to obtain information on rooms, furniture, equipment, teaching aids, and library facilities, as well as on methods of purchasing and sources of money. Findings are that classroom facilities are usually inadequate and that fewer than half the mathematics teachers replying use commercial or improvised equipment even though models were rated the most valuable teaching aid. Another government survey by Martin (1960) reported requirements and recommendations of state departments of education in regard to facilities, equipment, and instructional material for teaching science and mathematics at the elementary-school and secondary-school levels.

College Preparation and Entrance

Despite considerable emphasis on mathematics preparation and curriculum changes, few investigations have reported implications for college entrance and preparation. G. B. Smith (1958), analyzing the preparation of 1124 freshmen entering the University of Kansas in 1956, found that 29 percent of the men and 5 percent of the women had four or more years of mathematics. Forty-seven percent of arts and science students, 81 percent of engineering students, and 28 percent of fine arts students had three years.

Keedy (1959a), using questionnaire returns from 134 engineering schools, learned that 38 required solid geometry for entrance; he concluded that solid geometry was not significant in relation to entrance to engineering. Brant (1960) followed up Keedy's study by asking 51 schools with some kind of solid-geometry requirement if they would accept a one-year course of plane, solid, and co-ordinate geometry. In the few instances where a solid-geometry requirement still existed and in the vast majority of remaining courses, a fused course would be accepted. Thus while three-dimensional concepts were still judged important, solid geometry, as such, was an uncommon requirement.

McLean (1960) surveyed the status of integrated algebra-geometry courses in California and sought to determine the acceptability of such courses to teachers and college directors of admission. Integrated courses were not commonly found, teachers disagreed as to the value of such courses, and colleges generally accepted such courses except for science majors. It was suggested that integrated algebra-geometry courses be offered only as a second track in the college-preparatory mathematics curriculum.

Comparative Mathematics Teaching

With increased interest in American education, more attention has been given to what is done elsewhere. Many teachers have visited other countries, and numerous informal observational studies describe a variety of mathematics programs and suggest comparisons.

Woodby (1957) found in French secondary schools emphasis on national examinations and attention to modern mathematics, statistics, and co-ordination of physics and mathematics. Reform objectives were (a) classes four hours a week with no more than 40 students, (b) one hour a week in directed study ("half classes"), (c) better co-ordination of secondary and vocational programs, and (d) addition of suitable modern mathematics.

Wood (1958) discussed the expansion of secondary education in South Australia, the problem of appropriate mathematics courses for less able students, the virtual elimination of solid geometry, and the shortage of adequately trained teachers. Vogeli (1960), describing the mathematics program in Soviet 10-year schools, reported three trends: (a) polytechnism, (b) effort to lighten students' academic load, and (c) effort to raise the scientific level of mathematics instruction. Rourke (1960) observed these proposed changes in Russian secondary mathematics teachings: (a) elimination of trigonometry as an independent subject, (b) inclusion of analytic geometry in function study, (c) addition of computational trigonometry to geometry, and (d) addition of differential calculus to the eleventh year. Soviet self-criticism included (a) lack of emphasis on understanding, (b) liberalism in grading, and (c) lack of uniform standards.

Wirszup (1958, 1959) discussed the mass problem-solving contests held for Polish secondary students and mathematics requirements for secondary students in the Soviet Union, Poland, Czechoslovakia, and Red China. According to Rollett (1960), because of examinations and government assistance, secondary mathematics teaching in England tends toward uniformity, even though schools are free to plan curriculums. Up to half of advanced secondary mathematics was devoted to mechanics and often included elementary statistics. Bodenman (1959) described mathematics requirements and content in the Federal Republic of Germany. Pólya (1960), discussing the teaching of mathematics in Switzerland, noted emphasis on specialization after grade 7, emphasis on subject matter in teacher training, the advanced nature of mathematics in university preparatory schools, and the lack of recent or likely change.

Doremus (1957) reported on an exchange of test data between British and New Jersey schools. Gattegno (1958), visiting U.S. schools, observed (a) an unusual lack of professional trust of teachers, (b) little productive research, (c) need for relating course content to grade level, and (d) emphasis on instruction rather than on learning. A. W. Jones (1958) also visited American classrooms and noted (a) failure to make mathematics interesting, (b) failure to integrate algebra and geometry, (c) over-

reliance on textbooks, (d) emphasis on time units rather than on understanding, (e) less emphasis on mental arithmetic than in Australia, (f) poor blackboard and student work, and (g) less time for individual help and work than in Australia.

Research Reviews and Proposals

Financial support by governmental agencies and foundations for research in mathematics education should result in improvement in quality as well as quantity of research in mathematics education. An illustration of this support in action is the U.S. Department of Health, Education, and Welfare, Office of Education (1960) report of a conference on "Psychological Problems and Research Methods in Mathematics Training." This conference brought together mathematicians and psychologists to discuss approaches to research in mathematics education, and the report provides a guide for investigation of mathematics education. It includes a review of completed research, formulation of problems in the learning of mathematics which should be investigated, and research methods and designs appropriate to the conduct of such studies.

The U.S. Office of Education continued its semi-annual survey of research in mathematics education. The latest surveys by Brown and Kinsella (1960) and Brown (1958) included a summary of completed studies during 1957-58 as well as a listing of questions which need solutions. Unfortunately, this survey is not a complete listing of all research in mathematics education in 1957-58, since many persons fail to submit information on the research completed.

Summary

Studies reviewed in this chapter point to these general conclusions: (a) there is urgent need for more well-trained secondary mathematics teachers; (b) facilities for the teaching of mathematics need substantial improvement; (c) although much curriculum development has occurred, there is yet need for co-ordination, better definition of goals, concepts, and understandings, and adequate evaluative research; (d) although teaching by television has attracted much interest, the appropriate uses of such instruction are not yet clear; (e) some evidence suggests that we have in many instances expected too little from our students; however, the precise implications for secondary mathematics and the secondary school as a whole are still a moot point; (f) much curriculum study has been fragmented with emphasis on one level or another rather than concentration on the total program; (g) opportunities for the talented student have been greatly extended, but again without adequate evaluation and without adequate attention to the total situation.

Research should make maximum use of the techniques, instruments, and conclusions of previous studies of related problems. Johnson's (1957a)

summary of the implications of studies in the psychology of learning is indicative of the contributions to be found outside the field of mathematics.

In view of the increased cost and complexity of a well-designed study, Brown (1958) suggests that (a) key problems be identified by groups of teachers and schools; (b) problems be investigated by means of a team approach rather than by individuals; (c) results be published and distributed to avoid duplication and to suggest deeper studies. These are basic needs.

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CHAPTER V

The Academic and Professional Preparation of Teachers of Science

HERBERT A. SMITH and GUY B. HOMMAN

THE PERIOD reviewed has been marked by an intense interest in problems associated with teacher education for science. Reports have come from professional associations, accrediting agencies, state departments of education, and other independent groups, but research investigations, as such, are relatively meager. There is an extensive literature which includes many tacit assumptions untested by objective inquiry. However, because of the impact which many of these reports are likely to have on teacher education, some are noticed here.

Central themes which relate to the training of science teachers recur. They may be grouped into the following categories: (a) an increased concern that a modern view of the nature of science as process and as a mode of inquiry be developed; (b) a more adequate program of science training suited to the needs of elementary and secondary teachers; (c) a more realistic understanding of the complexity of the teacher's task; and (d) a recognition of the need for broadly educated teachers with balanced training in general, professional, and academic areas.

Background and Philosophy

Hurd (1958) contended that science should be taught as an intellectual achievement of man stemming from his desire to understand the forces which control and give meaning to the physical and biological world, the aim of instruction being depth and quality of understanding. The usual descriptive cataloguing of information in a taxonomic classification is unsuited to the achievement of objectives compatible with a real understanding of the scientific endeavor. Hurd further pointed out that teachers in the future will require training which considers conditions that influence scientific discovery, the nature of the creative process, and the tools employed.

Teacher Orientation

A number of articles dealt with the teacher's orientation to his task. Hurd called attention to the teacher's function as interpreter and mediator and distinguished between the kind of training this requires and the kind of training necessary for research scientists.

Brown (1958) and Garrett (1959) both argued the impossibility of training secondary-school teachers in four years and believed that five or even six years' schooling may eventually become standard practice. Schwab (1960) urged thorough reorientation to the role of the laboratory for the prospective science teacher. The laboratory, he contended, should be viewed as a place where nature is seen "more nearly in the raw" and where "things seen" are used as occasions for the invention and conduct of programs of inquiry. Present-day programs do not adequately provide this kind of training.

The National Association for Research in Science Teaching (1960) and Boeck (1960) urged more serious consideration to higher-order objectives in teacher training. They saw need for achieving the "pervasive objectives" of science instruction: appropriate attitudes, appreciations, and skills identified with critical thinking.

Teacher Training

Smith (1959) discussed the components necessary to the training of science teachers. Garrett (1959) and Hurd (1958) pointed to the need of a mathematical background. Brown (1958) discussed programs designed to enhance the competence of teachers. Pierce (1960) and Mallinson (1958) emphasized science teachers' need for both breadth and depth in subject-matter content.

Preservice Education

A number of studies supported the contention that many teachers, both elementary and secondary, are not adequately qualified to teach science.

Preparation of Elementary-School Science Teachers

Challand (1956), studying practices and conditions of science teaching in elementary schools in Illinois, appraised those practices by established principles of education. In general, teachers were concerned with appropriate objectives but failed to provide adequate opportunities for achieving them. They made insufficient use of materials and methods suited to instruction in science. Their training favored emphasis on biology over the physical sciences, and two-thirds of them had never had a course in audio-visual education. Only one-third of the schools offered an inservice program which provided opportunity for professional growth in science content.

Tyndall (1960) examined the science program at Atlantic Christian College for prospective elementary teachers, compiling high-school and college courses taken and computing grade-point averages. Separate check-

lists were employed for observations of teaching, and an interview checklist was used. Teachers generally did not perceive the importance of "laboratory-like" classroom teaching. An important finding was the lack of a significant relationship between the courses taken and the quality of teaching. This needs extensive and considered examination in view of the current emphasis on "depth" of training. It should be noted, however, that Tyndall's checklists may not have been appropriate to determine such a relationship. For one thing, the responses were subjectively evaluated. Perhaps the general question of the value of such training is more appropriately related to student performance *per se*. Tyndall made a number of recommendations for improvement of the Atlantic Christian College program, and some should be useful to other institutions.

Gega (1958) investigated problems of California teachers in presenting elementary science and the adequacy of college methods courses to meet these problems. He set forth a number of findings, conclusions, and recommendations. Problems were associated with (a) recent philosophies and points of view, (b) the inadequacy of teacher-training programs, and (c) teachers' unawareness of the problems of teaching elementary science, especially those related to objectives and evaluation. Among his recommendations were that (a) admission to the methods course should be contingent on passing a subject-matter examination and (b) methods courses should be taught by a faculty member with elementary-school teaching experience. The findings, conclusions, and recommendations of this study seem to have quite adequately circumscribed the major problems identified with the preparation of elementary teachers for responsibilities in science instruction.

Preparation of Secondary-School Teachers for Science Teaching

A large-scale study of science and mathematics teaching facilities, by the National Education Association Research Division (1959), revealed that among 5200 science teachers questioned, about half (49.3 percent) were employed as full-time teachers of science. Experienced teachers were better prepared in terms of credit hours than beginning teachers, although the differences were not marked.

The most disconcerting fact reported was that more than 5 percent of all teachers have only nine or fewer credits in science, and 0.3 percent have no training in science at all. Between 21 and 22 percent have fewer than 20 hours in science fields. These facts do not consider the appropriateness of the person's science background to his current assignment, and thus present a more optimistic view than is warranted. This study also sampled the opinion of principals on factors necessary to improve teaching. The greatest single need they saw was increased and more up-to-date knowledge of science.

Brown and Obourn (1959) studied qualifications and teaching loads of 1393 mathematics and science teachers in three states, examining such

factors as age, recency of training, degrees held, teacher migration, and professional and academic preparation. An average of 47.4 semester hours in college science was reported for 98.5 percent of the science teachers; however, 1.5 percent had no college training in science. They found that there were deficiencies in the general backgrounds of many science teachers in related science fields, in mathematics, and in professional training.

Gardner and Richardson (1960) analyzed Ohio State Department of Education reports of principals for 1957-58, collecting data on 2222 teachers. Their findings, paralleling the findings of the NEA study at the national level, revealed that 5.07 percent of the biology teachers, 6.63 percent of the chemistry teachers, and 9.58 percent of the physics teachers had no credit in their teaching area. Fewer than half the physics teachers had as many as 15 hours credit in physics. The low level of training in their teaching field cannot be attributed to a low level of educational attainment. More than 35 percent of the teachers had the master's degree, and 63 percent had the bachelor's degree. Only 29 of the 2222 had not earned the equivalent of a bachelor's degree.

Pella (1958) analyzed Wisconsin Department of Education data on the academic training of 258 physics teachers, 367 biology teachers, 261 chemistry teachers, and 407 general-science teachers. The categories were not mutually exclusive; for instance, a physics teacher might also be included as a general-science teacher. More than 4 percent of the teachers had no academic training in the subject taught. The general problem of variability of training and appropriateness of assignment is again encountered, however, since the median number of hours in science for part-time and full-time science teachers was 42 for physics teachers, 41 for biology teachers, 43.3 for chemistry teachers, and 39 for general-science teachers. Excluding general science, the average preparation of the Wisconsin science teachers was 17.5 semester hours in the specific subject taught.

Pella pointed out that college credit as a sole criterion for competence to teach in a particular area may be suspect, and saw both a quality factor and a time factor affecting adequacy of background. A study by Koelsche (1959) of Ohio teachers revealed essentially the same findings. Several studies revealed, directly or indirectly, a high rate of turnover and short professional life of science teachers. In a small and limited study, Winier (1957) observed that science majors are frequently interested in becoming administrators.

By questionnaire, Novak and Brooks (1959) recorded the judgment of 196 high-school teachers of science as to the preparation necessary to teach high-school science. They found the teachers' recommendations modest in terms of required college preparation, but that even their modest recommendations exceed certification requirements. Many science teachers are themselves satisfied with little or no basic college course work in science subjects taught in the high school.

Inservice Programs for Science Teachers

The need for inservice training of many teachers is conclusively demonstrated by the previously cited studies. Extensive opportunities for securing such training exist. Peterson (1959) reviewed the many educational programs supported by the National Science Foundation.

Schlessinger (1957), polling 934 participants in the 1956 NSF summer institute program, received 83-percent response and found that fewer than 0.7 percent of the participants had no degree, 43.6 percent held a bachelor's degree, and 53 percent had both master's and bachelor's degrees. One-third of those with master's degrees had majored in science or mathematics. Participants in the NSF institutes were better trained than the majority of science teachers, and respondents believed that the primary objective, to increase subject-matter competence, had been accomplished. Schlessinger saw need for graduate courses in content fields for high-school teachers and for a course emphasizing methods and techniques of science and mathematics teaching at the high-school level. It is perhaps significant that Kessel (1958) and Mallinson (1958), working independently, identified a considerable trend toward the implementation of graduate programs more specifically designed to meet the needs of science teachers.

Sims (1958), developing an inservice program for elementary teachers, held 11 sessions during the school year. A pretest and a post-test in science were administered to fourth-grade and fifth-grade classes whose teachers participated, and the results were compared with those obtained in control classes whose teachers did not participate in the program. Statistical analysis, which held intelligence and pretest scores constant, showed that the experimental classes achieved more on the post-test than the control classes.

Teacher Certification

The period under review saw an intensification of interest in certification and related problems, and there were co-operative efforts by diverse professional groups to improve present programs. Though the impact of this work will be great, it is not reported here since it hardly qualifies as research. Certification requirements for science and mathematics teachers in the United States were examined by Sarner and Frymier (1959). In the subject-matter area, requirements ranged from zero to 24 semester hours in mathematics, zero to 48 semester hours in science, and 12 to 24 semester hours in professional education. Some states accept high-school work toward meeting the requirement. The authors, observing that certification requirements are not uniform and are generally low, saw need for a uniform minimum code of requirements. They reported that 10 states have increased certification requirements or are currently considering revision.

Miscellaneous

A number of articles dealt with facilities and materials for a teacher-training program. Richardson and Schlessinger (1960) described facilities available for the science-teacher training program at the Ohio State University, a flexible classroom-laboratory.

Summary

Great shortcomings exist in the competence and preparation of elementary and secondary science teachers. Research has not really come to grips with the qualitative aspect of training programs. Considerable attention is given to quantity of training in terms of course hours and, to some extent, the competencies desired. Nevertheless, specific studies designed to determine the quality of existing programs are conspicuous by their omission.

To satisfy the need for both depth and breadth in training, the four-year bachelor's degree program is less and less adequate as preliminary training for secondary science teaching. Existing programs for elementary-school teachers are extremely inadequate. There is uncertainty as to responsibility for teacher training. It is not universally regarded as a responsibility to be shared co-operatively by professional departments, academic departments, the teaching profession at large, the state departments of education, and administrators. Continuing problems are turnover of personnel, movement of teachers into administrative positions, and means to attract high-quality young men and women to science and mathematics teaching.

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CHAPTER VI

The Academic and Professional Training of Teachers of Mathematics

JOHN A. BROWN and JOHN R. MAYOR

WITHIN the last three years, thousands of mathematicians and teachers of mathematics at all levels have taken part in studies designed to ascertain ways of improving mathematics instruction. No earlier review period has seen investigations comparable to the current massive effort and its results.

The investigations have been concerned with mathematics programs from the kindergarten through the graduate school. A first goal of many studies has been the production of sample course materials; the implications for and effect on teacher education are far-reaching. The academic and professional training of teachers must take into account the changing mathematics curriculum. All the groups preparing and trying out new materials have recognized the related teacher-education problems, and almost all have carried on investigations specifically concerned with teacher education. Jones (1960) emphasized implications of research in mathematics for teacher education in a paper before the American Association of Colleges for Teacher Education.

Some 20 separate studies in mathematics curriculum were under way during the review period. The School Mathematics Study Group (SMSG) of mathematicians and teachers in all parts of the country, which has an advisory committee appointed by the presidents of the three major national mathematical societies, has offered its co-operation to all independently operating centers of activity and is in a position to take advantage of the good work of the other groups. A major concern of the SMSG is teacher education. Another kind of investigation which has equally far-reaching implications for teacher education is the growing interest of psychologists in learning theory as related to mathematics. This research is best exemplified by the work of Bruner (1960).

Research in mathematics and science is often classified as basic or applied. Duncan and Frymier (1960) made this distinction for research in teacher education. This review, more concerned with applied research, reviews studies peculiar to mathematics-teacher education rather than studies which have implications for teacher education generally. Moreover, a greater proportion of the former is clearly applied, particularly the investigations of course content. Research dealing with the way children learn mathematics, since it has important implications for other fields, may come to be classified as basic.

The first group of studies noted here consists of those which bear on research in teacher education and give promise of determining its direction for the rest of this century.

Studies Affecting Research in Teacher Education

The College Entrance Examination Board (CEEB) Commission on Mathematics (1959b) recommended that algebra be presented from the point of view of contemporary mathematics. The Commission stated that the goal of instruction in algebra should be oriented toward the development and understanding of the properties of a number field. Both skills and concepts were pointed to as essential.

There has been, and continues to be, extensive research in the development of new algebra courses. The School Mathematics Study Group (1960) course covers essentially the same ground as a conventional first-year course but differs in that it is based on structure properties of the real number system. Simple deductive proofs are developed from carefully worded definitions and axioms. The University of Illinois Committee on School Mathematics (UICSM) (1959 a, b, c, d) algebra course also emphasizes structure and uses the language of sets and logic. Exercises are carefully developed to facilitate discovery of mathematical ideas by the student. The Ball State experimental algebra course stresses axiomatic structure, and students are expected to proceed intuitively. Concepts of set theory and logic are studied. Brumfiel (1959) reported that students who have taken the Ball State course do better in axiomatic geometry than others.

Research by Piaget, Inhelder, and Szeminska (1960) indicated that youngsters can grasp the idea of logical operations basic to probability such as disjunction and conjunction. Statistical manipulation and computation were seen as tools after the idea of probability is intuitively grasped. Probability as an alternative high-school course was recommended by the College Entrance Examination Board Commission on Mathematics (1959a).

The Commission also recommended the following content for a geometry course (or mathematics) for grade 5: informal geometry, deductive reasoning, a sequence of theorems culminating in the Pythagorean theorem, co-ordinate geometry, and solid geometry. SMSG geometry differs from conventional geometry in its postulational system, which is like that of Birkhoff and is complete. A distinguishing feature is the free use of the real number line. The topics covered in the text are fundamentally the same as the topics covered in conventional high-school geometry books.

The Commission and the SMSG agreed on the desirability of a course in elementary functions for one semester of the senior year. Schools are now trying out the probability course prepared by the Commission, and a course in matrix algebra prepared by SMSG, as possible second-semester

courses. SMSG and the University of Maryland Mathematics Project developed new materials for use in grades 7 and 8. Garstens, Keedy, and Mayor (1960) emphasized careful use of language and attention to structures in the Maryland course.

Hendrix (1960) emphasized the large role played by nonverbal communication between teacher and student and pointed out that research in paralinguistics is successfully classifying the nonverbal behavior which human beings learn to recognize in each other. The role of an inspirational teacher of mathematics in the learning process was studied by Sanderson and Anderson (1960), who concluded that mathematics teachers judged to be inspirational by students favorably affect achievement as measured by a mathematics usage test, but that this superior achievement seems not necessarily to carry over into other academic areas.

Hutson (1960) reviewed major content requirements in Pennsylvania and all-university control of teacher education at the University of Pittsburgh. In an analysis of teaching loads in Pennsylvania secondary schools with 500 or more students in 1958-59 (schools of this size enroll 84.9 percent of Pennsylvania students), he reported 232 full-time teachers of mathematics (compared with 37 mathematics-science teachers and 18 mathematics—social-studies teachers). Burger (1960) studied teaching load and preparation of 1037 mathematics teachers in Kansas for 1957-58. Sixty percent of the teachers were over 35 years of age, and 66 percent had been in their present positions no more than five years. Slightly fewer than one-third had majored in mathematics. One-eighth of those who held the master's degree had majored in mathematics at that level. Twenty-one teachers had no college credit in mathematics. Only 42 percent had completed a year's course in the calculus.

Attempts to assemble specific information on preparation and teaching load of mathematics teachers continued. Brown (1960b) reported a sampling study made in three states by the U.S. Office of Education. A sampling study for the country is being developed by the Teacher Preparation-Certification Study of the National Association of State Directors of Teacher Education and Certification, following some of Brown's procedures and making use of the U.S. Registry of Junior and Senior High School Science and Mathematics Teaching Personnel (American Mathematical Monthly, 1960d).

Course Offerings for Secondary-School Teachers

Academic training of mathematics teachers will be largely determined for the next decade or longer by recommendations of the Mathematical Association of America Committee on the Undergraduate Program in Mathematics (CUPM) (1960). CUPM and SMSG work in close association. Three groups connected with the American Association for the Advancement of Science carried on careful studies of mathematics-teacher

education, as a part of science-teacher-education studies. A new department of the *American Mathematical Monthly*, called "Mathematical Education Notes," made possible dissemination of information on local, regional, and national studies. It is accurate to state that research in mathematics-teacher education for the period of this review was largely concerned with academic training.

Anderson (1960), Buck (1959), Busemann (1960), Denbow (1959), and Meder and others (1959) described specific undergraduate courses to prepare for teaching, including algebra, analysis, geometry, probability and statistics, and computing machinery. The issue of whether these courses should be for teachers only was not clearly resolved. Northrop (1959) reported on a new course for teachers in which preparation of teaching units is related to content studied.

Six authors reported on methods courses in mathematics for prospective secondary-school teachers (American Mathematical Monthly, 1960b) which were developed after local experimentation and tryout. These courses are offered by a mathematics-department staff member in cooperation with the department of education. Learning through personal, purposeful involvement in the learning situation was analyzed by Richardson and Schlessinger (1960), discussing a center for science and mathematics education.

Committee recommendations for undergraduate course sequences sometimes included a fifth year. There was general agreement among the CUPM; the CEEB Commission on Mathematics; the American Association of Colleges for Teacher Education and American Association for the Advancement of Science, Joint Commission on the Education of Teachers of Science and Mathematics (1960); the American Association for the Advancement of Science Cooperative Committee on the Teaching of Science and Mathematics (1960), in their "Garrett Report"; and the National Association of State Directors of Teacher Education and Certification and American Association for the Advancement of Science (NASDTEC-AAAS) study, reported by Young (1960), that year courses in calculus, modern algebra, and geometry are essential for secondary-school teachers. There was some disagreement on details and related study. For example, the AAAS groups recommended more work in the physical sciences than did the others, and there was different emphasis on probability and statistics.

The most vocal critics of education referred less to European practices as they learned more about American. Lindquist (1960) reported that Russian secondary-school teachers are trained as subject-matter specialists in a five-year pedagogical institute based on 10 years of general education. Within every five-year period teachers must attend an institute. Prospective teachers take a double major, for example, mathematics and physics. Pólya (1960), discussing mathematics education in Switzerland, emphasized the extensive subject-matter training of Swiss teachers.

Need for improved inservice programs for secondary-school teachers was emphasized by Brown (1960a), and some innovations experimental in nature were reported. "Continental Classroom" courses in mathematics provided important modern courses for teachers who need them, and also served as model courses for interested colleges. Gustad (1959) gave a complete analysis of the evaluation of the *Study on the Use of Science Counselors* of the American Association for the Advancement of Science (1957). Denmark (1959) showed how a junior college can help.

State curriculum studies, such as those of the Oklahoma State Department of Education, Oklahoma Curriculum Improvement Commission (1960), became important factors in inservice education. The use of National Defense Education Act (NDEA) funds in inservice education by the Department of Education in California, reported by Lindsay (1960), pointed a way to new developments under a revised NDEA. Hendrix and Sims (1960) described the UICSM teacher-training films, intended for both preservice and inservice teachers and showing actual learning experiences of children.

A new factor of great significance to research is use of teaching machines. Blyth (1960) told of experiences at Hamilton College in teaching logic by machine. Tulock (1958) projected new horizons in the preparation of mathematics teachers resulting from recognition of the importance of content study, knowledge of related industrial developments, all-college planning, and systematically planned programs throughout the career of the teacher.

Mathematical Preparation of the Elementary Teacher

Attention was given to appropriate course offerings for the prospective elementary teacher. Many state elementary-teacher certificate requirements do not include credit in mathematics. However, as colleges and universities develop better courses in mathematics for this group, more states will add such a requirement. In the NASDTEC-AAAS regional conferences, a four-semester sequence for elementary teachers entering college with only two years of high-school mathematics was approved by certification officers as well as mathematics teachers.

There was a trend toward courses combining mathematics content and method (American Mathematical Monthly, 1960a). As a part of the American Association for the Advancement of Science (1960) education project, Emory University mathematics and education staff are jointly planning, teaching, and evaluating a mathematics course. Similarly, Oklahoma State University is testing a way of motivating prospective elementary teachers of mathematics and science by student teaching in the junior year followed by additional work in content areas in the senior year.

Smart (1960) reported on a summer institute for elementary-school teachers and supervisors under National Science Foundation sponsorship. At the University of Maryland an experimental inservice program in mathe-

matics for elementary supervisors and teachers, making use of the junior-high-school materials developed at Maryland, is in progress.

John (1960) reviewed basic mathematical content needed by elementary teachers in preparing students to study successfully the new mathematics courses at the secondary-school level. Analysis of topological ideas by Anderson (1960) relevant to the new junior-high-school mathematics supported John's view.

A number of colleges investigated inservice education projects for elementary teachers. Osborn and DeVault (1960) revealed enthusiastic acceptance of such projects by teachers when the mathematical content is closely related to teaching problems.

A new dimension in the preparation of elementary teachers is now clearly on the horizon, due to the increasing trend in elementary-teacher-education programs to require a major or area of concentration and to the new interest in the use of special teachers before grade 7. The American Association for the Advancement of Science (1959) is carrying on a study on the use of special teachers in science and mathematics in grades 5 and 6 in Cedar Rapids; Lansing; Washington, D.C.; and Woodford County, Kentucky. The research design includes tests of social attitudes and general intelligence as well as pretests and post-tests of achievement. A similar investigation known as the Dual Progress Plan is under the sponsorship of New York University.

Certification

The working papers for the 1960 conference of the National Commission on Teacher Education and Professional Standards, in the June 1960 issue of the *Journal of Teacher Education*, provided basic information for research and understanding of teacher certification as a complex component of the total teacher-education process. Stinnett (1960) found that all states now require a bachelor's degree for the beginning secondary-school teacher and all but eight require this minimum for the beginning elementary teacher. The range of required semester hours in professional education was from 12 (Arkansas, Maine, Massachusetts) to 27 (Washington). The modal requirement is 18 semester hours. Umberger (1960) reported an increased concentration in subject-matter-major content from a minimum of 15 hours to 30 hours in Connecticut, reflecting a widespread trend. Many states are revising certificate requirements (in mathematics and other subjects) upward in view of needs for teaching the new courses in mathematics and in answer to criticism.

The NASDTEC, with the co-operation of the AAAS, embarked on a co-operative study with scientists of what prospective secondary-school teachers of mathematics and science should learn about their subjects in college. Viall (1960) reviewed the process of the study and pointed out the participation of leaders of current curriculum studies. Young (1960), a participant in one of the regional conferences, spoke encouragingly of

the hope for improvement which should result from closer working relationships among mathematicians, teachers, and state-department personnel, and the impetus the study might give to state action research.

The use of proficiency examinations for teachers is a subject of debate in both academic and professional-education groups. Reference to this debate appeared in a short statement, "Proficiency Examinations for Teachers" (American Mathematical Monthly, 1960c).

Need for Further Research

Research in learning and teaching has developed rapidly. Further research recommended by the Woods Hole Conference (Whaley, 1959) includes reference to inherent interest of materials taught; providing for student discovery; writing materials "into the thought forms appropriate to the child"; use of films, TV, recordings, and teaching machines; the nature of intuitive thinking and analytic thinking; and the role of structure and principles in learning. In the near future we can expect to see textbooks which are fundamentally "teaching machines." Extended research in classroom use of such materials is necessary to ensure proper teaching methods and procedures. Kinney (1958) pointed out the need for evaluating the curriculum in terms of the following criteria: whether it can be taught, whether it should be taught, social validity, relation to total program, and articulation.

Research on methods of instruction, improvement of teaching aids, and learning will be highly significant for teacher education. In addition we need to know a great deal more about special courses for teachers, sequences of courses for teachers, bases of motivation and the relation of the inspirational teacher to the learner, identification of teaching ability, and bases for approval and certification.

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CHAPTER VII

The Teaching of Science at the College and University Level

VADEN W. MILES and W. C. VAN DEVENTER

RESEARCH in college-level science education has increased greatly in the last 15 years. Reviews sponsored annually by the National Association for Research in Science Teaching in co-operation with the U.S. Office of Education and by the science-teaching societies affiliated with the American Association for the Advancement of Science present summaries of research at all levels, including college.

Teaching Methods

Frings and Hichar (1958) compared three laboratory teaching methods: (a) the "regular" method, using a manual in which identification and description of structures were illustrated by diagrams; (b) use of unlabeled diagrams and accompanying lists of structures; and (c) study of living specimens identical or related to those used in the other two procedures, with suggested experiments and questions. The students were given the same lectures and were divided into five laboratory groups, four of which were rotated as control (the "regular" laboratory method) and experimental.

Results of all methods were closely similar, and the results of a student methods-evaluation questionnaire were inconclusive. In deciding what method should be used, the major consideration, the investigators concluded, should be the interest, convenience, and preference of the instructor. This carefully planned and executed study bears out what has been indicated by other studies of this type: no one method of instruction, in and of itself, is better than others. Success is dependent on the instructor and what he does.

Breukelman, Andrews, and Novak (1959) reported a study in which three biology sections taught in a large lecture group without laboratory were paired with three taught in smaller lecture and laboratory groups. This study was carried on with successive groups of students over a three-year period. Each year the checks on the entrance tests of ability of the groups revealed no significant differences among them in any year or over the three years.

There was no evidence that students taught by the lecture-only method varied significantly in achievement from those taught by the lecture and laboratory method. Also there was no evidence of differential learning for the high, middle, and low-performance groups. Correlation coefficients between entrance examinations and performance in general biology were

relatively constant under both methods of instruction, though none were high.

The investigators concluded that (a) the lecture-only approach was apparently effective in teaching facts and principles; (b) lectures must be carefully planned and executed; (c) a greater proportion of staff hours must be allowed for student conferences; (d) audio-visual aids and distribution of lecture outlines, study questions, and diagrams are needed. Furthermore, it must be recognized that not all instructors are effective in teaching large lecture classes. They recommended further study of the effect of the lecture-only method on attitudes, ability to solve problems, and retention and understanding of biological concepts.

Lawson, Burmester, and Nelson (1960) described the development of a semi-automated teaching device called a "scrambled book." It is essentially a self-administered objective test, with accompanying addenda telling why each possible answer is right or wrong, with the whole arranged like a botanical key, telling the student where to go for the next step or alternative. Then the entire instrument is "scrambled" so that items and explanations do not follow in orderly sequence. Since the device is self-explanatory, it enables a single instructor to oversee the work of large numbers of students. The scrambled book requires that the student learn new ideas, and that he use these ideas in test situations frequently involving deductive thinking. It is a device that demands careful thought. It immediately checks and corrects errors.

The scrambled book used in this experiment replaced one week of introductory material in genetics. To construct it, a laboratory study of question-answer type was rewritten, carefully fitting each question with multiple-choice alternatives chosen either on the basis of previous experience wi'ı the unit or, if they were new questions, from students' free-response answers to a special test administration. No step in the thought sequence was omitted.

Five sections of the natural-science course at Michigan State University, using the device, were compared with five control sections on an objective test covering reasoning, analysis, and interpretation and application to new situations of what had been learned. Difference in performance was significantly (1-percent level) in favor of sections which had used the scrambled book. Questionnaire results indicated that the number of students who accepted the scrambled book and found it stimulating far exceeded those who did not. Staff comment was also favorable.

Research investigations dealing with college laboratory programs are few. Hilton (1957) proposed (a) to evaluate a laboratory program accompanying a college physical-science course for non-science majors and (b) to test experimentally a method of selecting laboratory experiments which would provide desirable science-education experiences for general education. In connection with the first objective he employed six criteria for the preparation of 15 one-hour laboratory experiments validated by the judgments of four specialists in college physical science.

In students' questionnaire evaluation of these experiments, they indicated that the laboratory was valuable (76 percent); that it improved understanding of the lecture topics (85 percent); and that experimental problem solving, by which answers, to be acceptable, must be based on evidence, was illustrated (93 percent). The laboratory experience on "The Heavens" ranked first in interest and general-education contribution.

In connection with the second objective, similar techniques were applied to the topics of mechanics, heat, electricity, and wave phenomena. Four physical-science specialists rated experiments for each area as to how well they illustrated science principles determined by appropriate research techniques. The highest-rated experiment and the lowest-rated one were used.

Laboratory Group I, in addition to hearing lectures, performed the experiment which the specialists rated highest and which also illustrated the most principles; Group II, in addition to lectures, performed the lowest-rated experiment which also illustrated the fewest principles; Group III, the nonlaboratory group, received only the lecture course. All three groups were pretested and post-tested with an examination on science principles. *L*-homogeneity tests indicated that the three groups were of equal variability. Simultaneously partialing out the effects of ACE scores and pretests by a complete analysis-of-variance-covariance technique, Hilton found no significant differences among either the four topical areas or the three groups.

General conclusions were that in college physical-science courses for nonscience majors (a) the opinion of students concerning the positive effect of laboratory is of questionable value where the objective results of experimental investigation indicate no statistical variation in knowledge of science principles among the groups which had lecture with laboratory and without laboratory; (b) a physical-science laboratory program is of little or no value in assisting students in understanding science principles; (c) because the laboratory program does not produce statistically better results as measured by the understanding of science principles, it is doubtful that any method of selecting the physical-science laboratory experiments could be identified as better than any other method. No evaluation was made of the value which the laboratory might contribute to the retention of knowledge of science principles and to the acquisition of scientific attitudes and of problem-solving skills.

Alterman (1957) determined the comparative effectiveness of two methods of presenting physics principles on the ability of college students to apply principles of physics to new situations. The control consisted of starting with a statement of a principle and then proceeding to illustrate and apply it—the deductive method. The experimental method attempted to develop a principle by demonstration and analysis of applications or situations before the principle was stated. The latter is presumably the inductive method.

Four nationally used tests showed no significant difference between the control and experimental groups on pretest. At the end of one semester of

physics each group took three tests: (a) a test of recall of facts in physics, (b) a test of ability to solve mathematical or formula-type problems in physics, and (c) a test of applications of principles of physics to new situations.

Statistical analysis of the data, using coefficients of correlation and a *t*-test, indicated that (a) the inductive method produced significantly better results only with students rating low on preliminary background tests and then solely on the test of application of principles to new situations; (b) the ability of students to recall facts and principles of physics is highly correlated with the ability to apply principles to new situations as well as with the ability to solve mathematical or formula-type problems in physics; and (c) the ability to solve mathematical or formula-type problems in physics is significantly but not highly correlated with the ability to apply principles to new situations.

In a somewhat similar unpublished study in general college chemistry, Stubbs (1958) concluded that (a) the superiority of the inductive over the deductive method is more apparent than real, and (b) the inductive method is more fruitful than the deductive method for training students in use of the scientific method of problem solving and procedure.

Teacher-Student Relationships

Sturgis (1960) described an investigation to determine the relation of teaching effectiveness to the teacher's knowledge of the student's personal background. Based on two criteria, student ratings of the teacher and student achievement, it involved six groups of students in sophomore physics (mechanics) and three teachers. Each teacher taught an experimental section and a control section; for each student in the experimental section the teacher had a transcript of the secondary-school and college record and a personal data questionnaire filled out by the student. At the end of the course, all the students rated the teachers, using the *Georgia Tech Faculty Evaluation Form*. Achievement of students was measured by the mechanics section of the *Cooperative Physics Test for College Students*.

Analysis of variance showed that the students in the experimental sections rated their teachers significantly higher and made significantly greater gains in test performance than those in the control sections. It was concluded that the effectiveness of teaching, as measured in terms of student achievement and student ratings of teachers, is to a significant extent dependent on the teacher's knowledge of the student's personal background. This study appears, therefore, to lend some support to the contention that in large classes, where the teacher is less able to know the students as individuals, less effective teaching takes place.

Blumenthal (1957) compared end-term achievement of general college physics students who had been taught in lecture, recitation, and/or laboratory by one instructor with the achievement of those who had more than one. Group I (N=49) comprised students who had one instructor for all

three two-hour instruction sessions; Group II (N=25) students had the same instructor for recitation and laboratory, but a different lecturer; Group III (N=85) students had different instructors for the three sessions. The criterion was a carefully constructed two-hour examination testing physics knowledge and problem solving in the fields of mechanics, heat, and sound. The semester's achievements of all the students (including the experimental Group I) for the three instructors involved were compared on the criterion test. Since no significant differences were found, the instructors were presumed equally effective teachers.

Using Snedecor F-ratios of variance, Blumenthal found no significant differences in achievement among the three groups in problem-solving ability, but the end-term physics knowledge of those who had the same instructor in lecture, recitation, and laboratory exceeded that of those whose lecture and recitation instructors were different. There was no significant difference in end-term knowledge between those who had the same or different instructors in recitation and laboratory.

Scientific Thinking and Scientific Attitude

Bass (1959) studied the relationship between achievement on subject-matter tests in freshman zoology and two standardized critical-thinking tests: the *Watson-Glaser Critical Thinking Appraisal* and the *Test of Critical Thinking* of the American Council on Education. The *Ohio State University Psychological Examination,* the *Iowa High School Content Test,* and the *University of Oklahoma Mathematics Placement Examination* were also used. Zero, first, and second-order correlations and multiple correlation were computed.

Coefficients of correlation between the subject-matter examinations and the two critical-thinking tests were found to be significant at the .05 level. The ACE critical thinking test and the Oklahoma mathematics placement test were the best predictors, but were not markedly better than the other tests.

DeProspo (1957) undertook to determine if identification of the problem-solving skills portrayed in selected motion pictures would reinforce or develop an attitude of suspended judgment in college freshmen. Students from general-biology and general-science courses at Seton Hall University were divided into (a) an experimental group, (b) a film control group, and (c) a no-film control group. Three films were used: *The Scientific Method* (shown first to introduce problem-solving skills), *Madame Curie,* and *Yellow Jack.* A "Scale of Suspended Judgment" was constructed in the form of a series of statements of opinion and subjected to a Thurstone-type analysis by a panel of science educators. The final form of 20 items had an index of reliability of .88.

The experiment covered three consecutive class periods in which the no-film control group continued its regular class work, the film control group simply viewed the films, and the experimental group was made aware

of the object of the experiment and given some prior motivation. This group identified the problem-solving skills and answered specific questions concerning them. The *Scale of Suspended Judgment* was used in all groups as a pretest and post-test, and again six weeks later to test retention.

The experimental group and film control group showed a significant gain in the desired attitude, but the difference between them was negligible. The no-film control group showed little change. The change in attitude in the two groups using the films was not related to scholastic aptitude or ability to identify the problem-solving skills.

Honors Students and Future Scientists

Lehmann and Nelson (1960) and Lehmann (1960) broke ground in a field of great significance, that of the outcomes of teaching superior students. The students were enrolled in honors sections of the natural science course at Michigan State University. These sections were designed to provide superior students with a situation in which they would be associated in smaller groups with others like themselves, would have an opportunity to go beyond prescribed subject matter, and would not be graded on the basis of a prescribed curve. The studies sought to ascertain (a) what the students hoped to receive from the honors section; (b) whether there is a significant difference between honors students and regular students in pretest scores, post-test scores, ACE (intelligence) scores, or final examination scores; and (c) the students' reaction to the honors experience.

Samples drawn from four honors sections were compared with samples from eight regular sections. It was found that the honors students had a significantly higher final examination mean score on the pretest and also on the post-test. The honors students had a significantly higher percentage of A's and B's on the final grade, which was a combination of the instructor's grade (50 percent) and the grade on a common final examination (50 percent). Analysis-of-covariance adjusting for both pretest and ACE scores showed no difference in achievement on the final examination and revealed that the differences between instructors were the significant source of variation rather than the variation between honors and regular sections.

The results of student-opinion surveys indicated that the honors students were more concerned with thoroughness and understanding than with memorization. However, only 28 percent of the honors students said that they were highly stimulated to do better work as a result of being in an honors section, whereas 46 percent of the regular-section students said that they were highly stimulated by the standard version of the course. The follow-up study showed further that a higher-than-expected proportion of the honors students used the program as an avenue for acceleration. This was contrary to the purpose of the program. In the opinion of students, the awarding of grades to honors students constitutes a problem.

Strauss (1957), Strauss and Brechbill (1959), and Strauss (1960) performed three closely related studies which attempted to discover and describe a pattern of characteristics common to those who profit from higher education to the extent of attaining the doctorate, particularly in science.

In the first study Strauss investigated the backgrounds of 89 men who had all earned the Ph.D. in physics, chemistry, or engineering at the Ohio State University, the University of California at Berkeley, or Cornell University. The high schools they had attended were visited and their records studied. Faculty members who remembered them were interviewed. It was found that 38 percent of them had IQ scores of 120 or less, and only 26 percent had scores of 141 or more. If an IQ of 120 is considered minimal for expectation of success in college, 38 percent of these men should not have attempted college, much less graduate work. Similarly, though all were in the top 50 percent of their high-school graduating class, 25 percent were below the top 10 percent, and only 10 percent of them were in the top 1 percent.

If it is not superior intelligence or high scholarship that marks the background of the future scientist, what common factors are there? After studying the backgrounds of a total of 169 scientists (including an earlier study not reported here), Strauss made the following tentative generalizations: (a) They possess to a unique degree the characteristic of "drive," which in a surprising number of cases could be correlated with some type of frustration in their early lives. (b) They indicate a certain degree of nonconformity which showed up early in life. (c) A third important factor appears to be encouragement by an adult.

The second study involved 30 biological scientists and 30 social scientists, all recent Ph.D.'s. A carefully structured interview technique was used and the interviews were recorded, transcribed, analyzed, and categorized. The chi-square technique was used to compare the two groups for each of the characteristics studied. The findings were essentially the same as those of the first study. A statistically significant difference was found to exist in the case of only 17 percent of the characteristics, which led the investigators to conclude that most of the traits studied were common to both groups.

The third study examined the backgrounds of 648 Ph.D. graduates of Johns Hopkins and the University of Maryland by means of a questionnaire sent to their high schools. There were 170 graduates in the biological sciences, 295 in the physical sciences, 107 in the social sciences, and 76 in the humanities. No study of their personal backgrounds was included, but the findings as to their IQ level were essentially the same as in the first study.

Principles of Science

Blanchet (1957) summarized work done on defining principles of various fields of science. Since studies of this type up to 1957 numbered more than

50, this summary is valuable and to a certain extent definitive. The following categories were used to include principles studied: (a) refinement of statements of principles, (b) formulation of lists of principles in different subject-matter fields, (c) evaluation of principles in terms of course content, (d) activities which contribute to development of understanding of principles, and (e) association of principles in one field with those in another.

Blanchet believed there is an ample number (more than 3000) of principles of science for use by textbook writers, teachers, and curriculum makers; and that there are many learning activities which can be used for developing understanding of these principles. He saw need, however, for refinement, and need for a set of criteria generally accepted as definitive for a principle of science. Principles need to be categorized as (a) large and inclusive or (b) subsidiary. The evaluation and refinement of principles need to be extended to include their ramifications in terms of classroom application and the dynamics of living.

Television

A chapter would be required to abstract recent studies which include the teaching of college science on open-circuit and closed-circuit television. Phrases such as "findings of no significant differences in achievement between students taught by television and those taught conventionally" were typical. However, these should not be interpreted to mean that there is no loss when a class is taught by television rather than in person. Television seems to be slightly inferior to conventional instruction in most college situations.

Summary

It must be realized that a limited treatment of the only sort possible within a chapter cannot survey or adequately recognize many fine research studies in college-level science education published during the last four years. We have selected a few which are outstanding in content and execution, or which sum up an area or break ground in a new area of importance.

It should be noted that at least one very important area of college-level science education has been left untouched for lack of objective research studies. That is evaluation of the quality of graduate-level science education achieved in the institutes supported by the National Science Foundation. In view of the rapid growth of these during the last four years and the increasing role played by them in the graduate programs of most university-level institutions, such evaluation should be undertaken.

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CHAPTER VIII

The Teaching of Mathematics at the College and University Level

GILBERT ULMER and DONALD TILLOTSON

THE LAST few years' unprecedented interest in improving the teaching of college mathematics is evidenced by reports in the *American Mathematical Monthly* of papers presented at section meetings describing new programs and by conferences and symposiums on undergraduate mathematics throughout the country. A greatly increased number of articles, a nationally televised course with a new kind of content, and the activities of such groups as the Committee on the Undergraduate Program in Mathematics, the Division of Mathematics of the National Academy of Sciences—National Research Council, the American Association for the Advancement of Science, the American Society for Engineering Education, and the Conference Board of the Mathematical Sciences give added proof of interest in the field.

The actual research reported is almost insignificant in comparison with those activities. As yet there has been almost no scientific study of the need for change in the content of the college curriculum or the effectiveness of any of the new curriculums. This is not to say that changes should not be made until the need for them is established or that new curriculums should not be continued unless their worth is clearly proved. Sufficient reason for change lies in the fact that mathematicians from universities and from industry agree that much of the mathematics developed in recent decades is important and useful, and should replace parts of the classical curriculum.

Little formal evaluation has been made of special provisions for superior students. Again, perhaps the benefits of enriched programs are so obvious that evaluation seems superfluous, or perhaps it would be difficult to design significant research in this area.

Teachers and Method

Two studies dealt with the teaching of college mathematics. Gavurin (1957) studied professional characteristics of teachers (a) in the 25 oldest colleges in the United States during the years 1888-1941, and (b) in a recent sample of 117 colleges of various sizes and types of organization. He found a range of training and professional activity in teachers in the latter group which tended to vary with the size and program of the college in much the same way as these factors varied with time in the former group.

Woo-Sam (1960) attempted to discover personal factors in teachers related to their teaching effectiveness as measured by student achievement. He found no factors on the scales used which varied significantly with such effectiveness. He also found no significant improvement in effectiveness as a result of counseling by a superior on the basis of the results of a student-rating scale.

Cummins (1960), experimenting with emphasis on student experience and discovery, prepared study guides and conducted class discussion so as to enable students to develop the concepts of the calculus for themselves. Comparison of the achievement of the experimental classes with control classes taught conventionally by another instructor indicated no significant differences in problem solving and skills but greater understanding of meanings.

Prediction and Placement

A problem in many colleges is accurate identification of students who may profitably begin their study of college mathematics with analytic geometry and calculus. Knights (1957) used the recognized techniques of test construction to develop and standardize an instrument for predicting success in analytic geometry. Also studying analytic geometry, Miller (1960) found that a combination of high-school average and scores on a trigonometry test had a predictive coefficient of .35.

Corotto (1958) found that both the *ACE Psychological Examination* and a locally constructed screening test would distinguish at a significant level between potentially successful and potentially unsuccessful students in their first mathematics course at the University of Houston. The screening test proved to be the better predictor. Schmidt (1958) found significant relations between scores made by entering freshmen on a junior-high-school mathematics test and their achievement in a general-mathematics course and in all courses at Florida State University. One measure tabulated was the ratio of credits earned with A or B grades to those with D's or F's for all students who scored in a given tenth of the test norms.

Graybeal (1958) considered interest inventories and biographical data as well as intelligence test scores and high-school averages in prediction of performance in college algebra. The predictive value of the data varied according to which of the following criteria was used: (a) achievement as measured by a standardized test or (b) success as indicated by the instructor's grade. Stone (1957) used the Wherry-Doolittle method to develop a multiple-regression equation to predict four-year averages in mathematics, physics, and chemistry. The significant variables were scores on the *ACE Psychological Examination*, one part from the *Minnesota Personality Scale*, two scales from the *Thurstone Temperament Schedule*, and the mechanical part of the *Kuder Preference Record*. The mechanical-interest score had a negative relation with the criterion. Riffenburgh

(1960), using a projective technique, did not find significant differences in personality traits between high achievers and low achievers in college algebra.

Attitudes

Cristantiello (1959), using a scale developed by Silance to measure the attitudes toward mathematics of college sophomores in business, social science, and science curriculums, found the majority to be favorable. The *Edwards Personal Preference Schedule* was used with students expressing extreme attitudes in an attempt to identify traits correlating with these attitudes. With the business and social science groups no such traits were found. With science students, favorable attitudes tended to accompany high scores on the endurance and achievement scales, and unfavorable attitudes correlated with the succorance and nurturance scores.

Tape-recorded interviews with students professing a fear of mathematics and with some high achievers were compared by McDermott (1956) in a study of possible causes of such fear. Dreger and Aiken (1957) established evidence of the existence of a "number anxiety" distinct from general anxiety by means of a modification of the *Taylor Manifest Anxiety Scale* and measurements of galvanic skin response.

Curriculum

During the period included in this review the undergraduate mathematics curriculum was the subject of much discussion and revision, which, however, involved relatively little formal research. Means (1958) submitted a list of 73 possible objectives for freshman and sophomore mathematics courses to a jury of experts and to mathematics teachers in seven Texas colleges. The agreement of the two groups in their over-all ratings of these objectives was evidenced by a correlation coefficient of .78. Means then sought to evaluate the extent to which the objectives recognized as valid were being realized at these colleges. To do this he examined catalogues, course outlines, and examinations from the institutions and administered a special test to a sample of the students.

In this study, certain objectives were criticized by some evaluators as properly being the concern of the high school rather than of the college. This agrees with the actions of some institutions in discontinuing remedial courses. Corotto (1958) found that students who took a remedial course were not significantly more successful in the next mathematics course than students of equal ability who had omitted the remedial course.

For terminal students in junior colleges, Rowe (1957) found that a course based largely on socialized arithmetic and elementary algebra with attention to the role of mathematics in the world today produced gains in mathematical achievement over that of students in a course in business mathematics or not enrolled in a mathematics course. A study of needs

and objectives led McNair (1959) to contend that one year of mathematics should be required of all junior-college students.

Layton (1957) found that of 91 colleges reporting a general-education program, only 46 required some mathematics. For the 91 institutions, the range in the amount of required mathematics was zero to eight hours, with a mean of 1.97. The mean number of hours of mathematics considered advisable by the respondents was 4.82. Agreement on topics desirable in such a required course centered on items from arithmetic and algebra. Milligan (1961) established objective criteria for validating topics in freshman mathematics and used them in constructing such a course. Changes in the calculus course during the present century were mapped by Mitchell (1958) from committee reports, college catalogues, and textbooks. New directions seemed to be established in 1910 and 1940.

In two matched classes of solid analytic geometry Pettofrezzo (1959) used the vector approach in one, the algebra of numbers in the other. A special test, previously validated, revealed no significant difference in achievement between the groups. Of perhaps greater importance might have been the ability of the groups to understand vector concepts in later courses.

Mathematics for Special Curriculums

By means of a least-squares technique, Horton (1959) arrived at a sequence of topics in freshman mathematics for engineers most closely matching the order of topics in nine texts. This was one part of a study of the reorganization of such a course to promote the formation of concepts. In his conclusions, he emphasized unification around the function concept, with intuitive presentations preceding formal developments.

Prentice (1959) identified the mathematical definitions and theorems involved in the study of electrical engineering, organized them in a complete logical development, and outlined a corresponding sequence of three year-courses. Ahmann and Glock (1959), comparing the achievement of agriculture students assigned to a special freshman mathematics course with that of an equal group not taking the course, found no significant difference in grade-point averages or marks in later mathematics courses between the experimental and control groups, perhaps because of the exposure of all students to some mathematical instruction in science courses. In immediate persistence and in gain in mathematical knowledge during the freshman year, data favored the experimental group.

Two projects involved the mathematics curriculum for students of the behavioral sciences. Becker (1959) outlined a course for sociology and economics students after seeking to identify the essential concepts. The Dartmouth College Writing Group (1958), under the direction of the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America, prepared two volumes of experimental test materials for a second-year mathematics course emphasizing topics useful

in the social and biological sciences. Programs for students preparing for positions in industry were studied by Hart and Wood (1959) by means of a rating scale. Head mathematicians in large firms indicated their opinions of the value for training applied mathematicians of the courses commonly offered beyond the calculus.

Programs for Superior Students

Honors sections of mathematics courses continued to challenge superior students. At Princeton, the program was extended to the junior year, whereas at Dartmouth, three "tracks"—standard, honors, and social science applications—were continued through all four years. May (1958) reported that a small honors group at Carleton College engaged in projects during the fourth semester after completing an enriched version of the freshman and sophomore courses in three semesters.

Other programs, not yet subjected to formal evaluation, were the independent-study plan required of all students at the College of Wooster (1958), culminating in a senior paper and a comprehensive examination; the undergraduate thesis at Reed; the College of Quantitative Studies at Wesleyan, where one-fourth of the student's time is devoted to projects and problems; undergraduate research programs as at Carleton College and the University of Kansas; and a course presented by a distinguished visiting lecturer at Haverford.

Organization for Large Enrollments

Increased enrollment in mathematics and lack of a comparable increase in number of competent instructors led to experiments in course organization. A desire to bring as many beginning students as possible under instruction of master teachers suggested such measures as large lecture classes, films, and television.

Two investigations of class size in elementary college mathematics, both conducted in Kansas, yielded conflicting findings. Notheis (1958) discovered no significant difference in achievement as measured by a standardized test between large and small classes at Kansas State Teachers College. Evidence based on class marks was in favor of smaller groups in a study by Simmons (1958) of classes at the University of Wichita. In each case large sections in 1956-57 were compared with smaller classes of the year before, with proper consideration given to possible variations in ability factors.

Films and Television

The importance attached to the use of films and television was indicated by the appointment of a Film Evaluation Board by the Advisory Board

on Education and the Division of Mathematics of the National Academy of Sciences—National Research Council (1957). Developments in the use of these media were reviewed by P. Jones (1958) in an issue of the *American Mathematical Monthly* largely devoted to articles on this topic.

A number of studies of the use of televised lectures revealed no significant differences in mean achievement between "video" and "nonvideo" classes. King (1959) used a conventionally taught class of a previous term for comparison. Other studies, by A. Jones (1958), Larney (1959), Gordon, Nordquist, and Engar (1959), and Allendoerfer (1958) used regular classes during the same term as controls. Benner and Rogers (1960) compared achievement with that of the norm population for a standardized test.

In most experiments, small discussion sections were held to supplement lectures; but in the investigations of Seibert (1958) and A. Jones (1958, 1959), the students met in classroom groups for a one-half-period lecture and remained for a discussion session led by an instructor. Dyer-Bennet and others (1958) reported the use of matched pairs of students in comparing achievement in video and large lecture classes in calculus. Another control used was the exchange of lecturers between the two groups at midterm. Only Elliott (1958) reported superior achievement by television classes. However, the closed-circuit lectures were later replaced by conventional lecture to a large class, in part because much of the improvement was attributed to the emphasis on self-reliance and careful preparation of assignments.

There was some evidence in the study by Gordon, Nordquist, and Engar (1959) at Utah that high-ability students achieved better with televised instruction and lower-ability students better in the classroom. However, a similar analysis by Dyer-Bennet and others (1958) at Purdue did not reveal significant differences. The reports of Elliott (1958) and Allendoerfer (1958) mentioned the effect on the general public of mathematics courses broadcast over educational stations. The presentation of expertly prepared courses in contemporary mathematics on the "Continental Classroom" series will probably be the basis for future research studies.

A different approach to effective use of faculty was tried at Oberlin, where a long period of independent study was inserted in the middle of a year course. Baum (1958) reported that the experimental group did not evidence inferior achievement on course content to that shown by a control group which attended class all year, and that scores on a special test of "learning-resourcefulness" favored the independent study group, although not to a significant degree.

Programed Instruction

It is expected that there will soon be a number of reports of the effectiveness of programed materials and teaching machines. Several programs

have been written for college mathematics courses, but there has been no evaluative research.

Summary

Despite the vast amount of activity in the teaching of college and university mathematics, little research was reported. Studies were conducted in local situations, usually by individual investigators, over short periods of time. Co-operative effort on important problems is needed to be carried out on a national scale and over extended periods of time. Research is needed in methods of training new instructors and graduate assistants, ways of developing imagination and creativity in the study of mathematics, evaluation of new curriculums in the light of carefully established objectives, and the operation of advanced-placement programs.

Additional areas in which research might be helpful are ways of motivating the study of mathematics, the teaching of linear programing at various levels, desirable curriculums for small colleges, and further study of the use of large lecture or television sections with small discussion and problem-solving classes.

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CHAPTER IX

Provisions for the Academically Talented Student in Science and Mathematics

JEROME METZNER and WILLIAM B. REINER

RECENT reports regarding provisions for meeting the educational needs of talented pupils in science and mathematics dealt with new curriculums, courses of study, administrative provisions, and after-school programs. Few gave evaluation findings other than general or subjective estimates of the success of the programs undertaken. In some cases the programs were too recent for evaluation to be complete or they had not been fully reported. In others, no systematic ratings or statistical appraisals were undertaken.

Mention of a study here does not imply that its research quality is high. Citation is intended to serve only as a general guide to those interested. The first part of this chapter deals with the talented student in science, and the second with the talented student in mathematics. Most of the investigations noted here were conducted at the secondary-school level. Although provisions are being made for the talented at the college level, little research on such efforts exists.

Provisions for the Talented Science Student

To fulfill the special needs, abilities, and interests of talented science students, many programs and practices have been developed; and as they are tried, evaluative procedures will no doubt be developed also. The following practices were usually linked with carefully conducted guidance and counseling programs: advanced courses in high school, such as electronics, experimental biology, and instrumentation; ability grouping; acceleration; enrichment; advanced-placement courses; college attendance of high-school students; research-participation programs (sometimes summer programs); seminars (sometimes with technically competent resource people); trips to science and mathematics centers; special assignments, projects, and examinations; participation in fairs, congresses, and contests; scholarship talent searches; special programs of independent study; science and mathematics student institutes; apprenticeships to practicing scientists and mathematicians; honors classes; tutoring by talented students; foundation programs (e.g., Joe Berg Plan, National Science Foundation); extra programs; special summer camps; improved teacher-education programs; block programing; television and film courses; early admission to college.

Provisions for the Talented in Elementary-School Science

Experimenting with teaching science to the intellectually gifted in four New York City schools, a teacher-specialist conducts a science program in 10 classes while the regular teacher remains in the room to establish a "carry-over" and a "team approach." This experiment, to be carried through 1963, will attempt to determine the effect of this special science instruction on the achievement of children in other areas and on the attitudes of the classroom teacher. No evaluation or progress reports are available.

Davis and others (1960) constructed a battery of tests designed to measure the mental characteristics of young gifted children which included the investigation of five basic skills: scientific knowledge, space conceptualization, vocabulary, number ability, and reasoning. The science test was conceived as having value in programs attempting to detect science giftedness at an early age. Findings indicated that the five intellectual abilities are only loosely related to one another but that they can be accurately measured in children as young as four to five years of age and that children gifted in one or more of these abilities can be identified.

Norris (1958) pointed out that certain principles seem to be common to most administrative procedures in caring for the gifted child: (a) There is little or no acceleration; enrichment predominates. (b) Separation of the gifted from the group is indicated as desirable, if only for short periods. (c) The earlier the gifted child is challenged, the better. (d) Subject matter is not as critical as building interests, habits, and attitudes. (e) It is wise to cater to strengths and special abilities. (f) It is important to find and develop special talents. (g) Parents' co-operation is essential.

Passow (1959) emphasized the need for opportunities at an early age for individual searching leading to reflection and discovery. The elementary science program can be enriched by (a) differentiated assignments which encourage depth of activity, (b) group projects which deal with topics at an advanced level, (c) extended materials commensurate with the learner's abilities and desire to delve deep, and (d) opportunities to work independently with difficult materials.

Simpson and Martinson (1961) listed several evaluative studies of the achievement of gifted elementary pupils in science. In general, brighter students made greater advances in a given year than did average pupils, judged by standardized test results.

Provisions for the Talented in Secondary-School Science

Schaefer (1958) described an advanced science course for gifted students in high school which included college topics, such as the use of the slide rule and the development of physical theories. Fetherston (1959) reported a summer honors program for young scientists in Michigan. The

course utilized seminars, field trips, and resource people. No evaluation had been completed at the time of this report. Summers (1957) provided experiences in college-level chemistry for gifted high-school students. Nine of the 13 who took the Advanced Placement Examination were successful in obtaining advanced standing. Norton (1959) described successful enrichment activities for gifted students in high-school science, including assignments of additional problems and exercises, special science clubs and organizations, state and national contests, and extended library services.

Waterman (1957) described the National Science Foundation (NSF) program in relation to teacher training, student-participation programs, curriculum development in improving science teaching, and providing better facilities for the gifted student in science and in mathematics. The foundation program is available for high-school as well as college teachers in science and mathematics.

A description by the University of the State of New York (1958) of 56 practices for gifted pupils in the secondary schools of New York showed many specific programs and practices currently being used in the teaching of science and mathematics.

Crandall (1959) edited a study involving two matched chemistry laboratory classes for academically talented students. The control group participated in laboratory work in the traditional manner. The experimental group used open-end experiments with stress on developing scientific reasoning ability, creative thinking, and scientific outcomes other than factual knowledge. No significant differences between the groups were found in results on (a) a test of science reasoning and understanding, (b) a test of critical thinking, and (c) a high-school chemistry test.

In 1959-60, as part of a program still in progress, 24 New York City schools offered advanced-placement courses to 2366 students, of whom 592 took the Advanced Placement Examination; 498 passed. The greatest number of pupils were enrolled in mathematics (813); chemistry (494) ranked second. Expansion of advanced-placement courses is being encouraged where special abilities of teacher and pupils make it possible.

Sams (1960) reported the use of rating scales by California high-school principals to appraise procedures for gifted science students. The criteria rated highest were individual encouragement and personal guidance, opportunity for enrichment and advanced study, and self-evaluation.

The Worcester Foundation, in co-operation with St. Mark's School (Massachusetts), has held nine-week summer programs for talented pre-college students since 1955, aided by NSF funds. The programs have effectively motivated students into science teaching and medicine. Cooley and Bassett (1960) evaluated the Thayer Academy (Massachusetts) summer program, in which talented eleventh-year students studied for two weeks at the academy under visiting scientists and professors. During the next eight weeks these students worked in industrial and university laboratories under the supervision of specialists and attended a weekly sem-

inar. The program produced considerable growth in their ability to screen hypotheses, interpret data, and reason quantitatively. Summer programs for gifted high-school science students were regarded as successful. Paschal (1960) described several such programs in science and mathematics.

Brandwein (1958) listed some secondary-school provisions for the gifted in mathematics and science, such as differentiated grouping, assignments, and texts; laboratory work beyond the required exercise and opportunity for individually conceived experimentation; and differentiated tests with scope beyond classwork. Differentiated grouping and differentiated organization utilize clubs, laboratory squads, tutorial groups, seminars, special lectures, and homerooms for students planning to specialize in mathematics or science. The school-within-a-school or honor school is another device for obtaining free play of aspiration in a uniform administrative organization.

Bish and Gilliland (1960) recommended curricular and administrative guidelines for supervisors seeking solutions to such problems as articulation, identification procedures, programing, evaluation, and community relations. The principal's role in developing the program was elaborated.

Current efforts to upgrade secondary science include modernization and reorganization of science courses to emphasize principles, broad generalizations, and conceptual frameworks. Technological and applicational objectives have been minimized. Laboratory work is oriented toward experimental, problem-solving approaches, rather than toward routine exercises whose outcomes are frequently obvious. Foremost among these efforts were those of the Physical Science Study Committee, the Biological Sciences Curriculum Study, the CHEM Study, and the Chemical Bond Approach Project.

Bristow and others (1958) pointed out the need for proper revision of course content and grade placement in physics, chemistry, and biology. They cited procedures used by the Physical Science Study Committee at Massachusetts Institute of Technology, which included simultaneous involvements of scientists and science teachers in developing learning units, tryout of the materials in classroom situations, and the training of teachers. The AIBS Biological Sciences Curriculum Study (1961) prepared an experimental volume of 100 "biological investigations for secondary school students," contributed by biologists, which are intended to meet the needs of teachers working with students of high ability and interest in biology.

Learning materials better suited to the abilities of gifted students were produced. Science textbooks for high schools were brought up to date and presented newer concepts, such as the bond theory in chemistry and advanced energy relationships in physics. More pure science and critical thinking were included in proportion to descriptive and utilitarian science content. Barnes and others (1958) developed criteria for selecting supplementary reading books in the sciences for gifted high-school students and assessed the relative importance of these criteria. A survey of the

literature yielded a list of 23 criteria. Questionnaire respondents ranked these criteria and suggested others which should be included. The criteria were then divided into those pertaining to the effect of the book on the reader and those pertaining to the intrinsic quality of the book. A list of 12 criteria for supplementary reading in science books for gifted high-school students was set up and recommended for use in upgrading the reading level of this group.

Provisions for the Talented Mathematics Student

The most common provisions for mathematics students were curriculum adjustments in which modern concepts, greater concentration of materials, and critical thinking were stressed. The following are being studied: (a) curriculum development, scope, sequence; (b) new materials; (c) teacher training; and (d) redesigning of teaching methods. Few reports, however, include evaluative statistics as to outcomes, since most of the programs are in early stages. They follow the pattern of those for science students.

Provisions for the Talented in Elementary-School Mathematics

The Kalamazoo (Michigan) Public Schools (1958) described provisions for gifted pupils at elementary and high-school levels in science and mathematics. Curriculum materials, methods of teaching, and pupil achievement were reported. The program, in the light of pupil achievement on several tests, appeared to be successful. Kough (1960) described basic administration of mathematics and science programs for gifted children: (a) enrichment; (b) grouping in specialized schools; (c) special classes; (d) honors courses, seminars, and special courses; (e) out-of-school activities; and (f) acceleration.

Simpson and Martinson (1961) described in detail 17 programs developed in various learning areas for students at all levels. In formal arithmetic processes, children in programs at the lower elementary level advanced two years over regular pupils in the same period of time. The University of Illinois Arithmetic Project (1960) is currently developing and testing units on special topics in Champaign-Urbana public schools and elsewhere for kindergarten classes and in grades 1 through 6. Although not specifically designed for gifted pupils, the project has many potential applications for them. New topics, such as informal geometry, are being introduced at the elementary level.

Provisions for the Talented in Secondary-School Mathematics

A number of programs for gifted secondary-school mathematics students were described. Dodes (1959) discussed the program at the Bronx High School of Science (New York), where courses on the electronic computer,

such as the IBM 650, are being taught; and Kieffer (1959) reported on the advanced-placement plan in the Cincinnati schools. Freese (1959) considered introducing college mathematics in the senior year of high school. Passow and Brooks (1959) discussed the identification of talented secondary mathematics students and proposed a curriculum for them.

A program for advanced students in mathematics, grades 10 through 12, was formulated by the National Council of Teachers of Mathematics, which, in conjunction with the National Education Association Project on the Academically Talented Student, published material including provisions for mathematically talented students (Vance, 1957). Fliegler and Bish (1959) reported several studies describing enrichment and modernization in grades 9 through 12. More courses were completed with high grades in less than normal time by the gifted.

Evaluations of pilot programs in Milwaukee Public Schools (1960) indicated that it is possible for superior pupils to complete the three-year mathematics sequence of grades 7, 8, and 9 in two years. Selected pupils entering grade 8 are ready for tenth-grade geometry. The accelerated tenth-grade mathematics class showed higher achievement over normal on tests in both intermediate algebra and plane geometry than did either the tenth-grade or the eleventh-grade control group.

The University of Illinois School Mathematics Program (1961), directed by Max Beberman, has produced instructional materials, developed teaching methods, and trained teachers in secondary-school mathematics since 1951. Much of the program has appeal for gifted children. The committee has three major theses regarding methodology: (a) There should be consistency in approach. (b) Pupils are interested in ideas. (c) Manipulative skills and understanding are complementary. The program has developed six units of instruction and plans five more in the near future. It operates in several high schools in Illinois, Massachusetts, and Missouri.

Lloyd and others (1958)—mathematics committee of the Invitational Conference on the Academically Talented Secondary School Pupil—made favorable reference to the exploratory programs conducted at the University of Illinois; St. Paul, Minnesota; Hunter College High School, New York City; Arlington, Virginia; Lincoln and Central High Schools, Philadelphia; Portland, Oregon; Montgomery County, Maryland; and the University of Maryland. They saw schools moving toward compressing algebra, geometry, and trigonometry into three years for gifted students in order to make provision for calculus in grade 12.

Needed Research

Evaluative research is needed to determine whether or not the present practices in science and mathematics programs for gifted students have been instrumental in realizing educational objectives. It is recommended that intensive studies be conducted on outcomes other than scholastic

achievement. For example, how effective is the program for the gifted in stimulating and nurturing creativity, critical thinking, and problem-solving ability? The administrative aspects need research analysis. For example, what is the most effective arrangement for laboratory work, size of classes, plans for pupils, independent and group study, cocurricular and extracurricular activities, and grading? What teacher attributes are most effective in helping the gifted realize full potential? What training program is needed to produce the most effective teachers for the gifted? What are the classroom, laboratory, and field-trip group dynamics that promote optimum interaction among gifted students and between them and their teachers? Answers to these questions are needed.

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CHAPTER X

The Methodology of Educational Research in Science and Mathematics

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SINCE a large proportion of the research in methodology during this interval was described in dissertations, these constitute most of the reports reviewed here. This chapter is restricted to the procedures used in investigations. No attempt is made to deal with curriculums, teaching techniques, background, results, or conclusions of the studies.

Surveys

About two-fifths of the studies examined were surveys, most of which gathered data by questionnaire; not all were validated carefully, particularly in the matter of prior submission to a jury.

Opinions, Attitudes, and Interests

Aylesworth's (1960) study of science teachers' attitudes toward problem solving involved much preliminary investigation. Observations and tape recordings were made of 20 classes in schools of various sizes and in various science areas. A preliminary questionnaire was sent to 20 teachers, and their responses were compared with the tape recordings before the final questionnaire was formulated. Belt (1959), measuring attitudes of high-school pupils toward science and scientists, found the accuracy-of-perception items (multiple-choice) less ambiguous than the Likert type (agree-disagree-undecided).

Teacher Background and Teaching Conditions

Searching for factors contributing to competency of elementary science teachers, Berryessa (1959) used supervisors' identification of 100 outstanding female teachers, and chose the top 25 and bottom 25 (as evaluated by the Science Program Evaluation Scale) to be tested by interview, the *Kuder Preference Record*, and the *Minnesota Teacher Attitude Inventory*. Factors examined included childhood experiences, credit hours in college science, enjoyment of reading science materials, confidence in supervisor's

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ability, grades in science, teacher attitude (MTAI), stimulation, and interest in science and in teaching science.

A comprehensive survey of the academic preparation of science teachers was made by Pella (1958), who obtained the names of science teachers from state departments of education records, secured their college transcripts, tabulated data to show whether or not the teachers were part-time or full-time science teachers, categorized schools according to 12 sizes, and reported on areas of teacher preparation in physics, chemistry, biology, earth science, health, and mathematics.

A Canadian survey of the mathematical competence of prospective elementary teachers was made by Nelson and Worth (1960), who compared the trainees with their American equivalents at Illinois and Boston universities. Data on 468 trainees at various levels in the Alberta Faculty of Education were secured by means of the *Phillips Achievement Test in Elementary Arithmetic* and *Glennon's Test of Basic Mathematical Understandings,* and by questionnaire for background. Comparison of Alberta and American means was made by use of the Cochrane-Cox method involving weighted *t*-values, with no assumptions regarding population variance.

Norton (1960) surveyed teacher load in science and mathematics, making use of the Douglass definition of a teaching-load unit: teaching and preparing for an average class of 25 pupils for one period of 50 minutes (ordinarily 84 minutes of work). A formula yielded the number of teacher-load units per week.

Survey by Textbook Analysis

Content, objectives, materials of instruction, and programs were surveyed by means of textbook analyses. For example, Wilson (1959) traced and analyzed the evolution of plane-geometry content by examining 12 textbooks published in the United States between 1811 and 1837, 13 between 1838 and 1863, 18 between 1864 and 1881, and 18 between 1882 and 1899.

Psychological Bases of Learning

Surveys of factors, concepts, processes, learnings, thinking, and trends leading to achievement in mathematics and science have been made in a variety of ways. Miller (1960) obtained data from individual interviews in which a randomly selected group of 40 pupils thought aloud as they solved seven verbal arithmetic problems. Recordings were made of all responses. Jones (1959) analyzed excerpts of anecdotes in order to compose a list of beginning learnings which appeared to have resulted from "science experimenting to find out" by first-grade children. Stein (1960) surveyed the literature for changes in ideas regarding objectives, content,

method, teaching aids, and needed research in secondary-school mathematics.

Post (1958) used a confounded factorial design and analysis of variance in determining the significance of main effects and several minor-order effects of interaction of factors affecting the understanding of verbal problems in arithmetic. Factors included size of numbers, superfluous numerical data, familiarity of setting, number of steps, type of operation, and symbolic terms. Each factor was defined at two levels, making 64 different combinations in the study.

Status Surveys of Programs

Status-survey research provides data for comparative education. Faber (1960) used a survey team to visit Florida schools in order to observe provisions for high-school science. Lucow (1960) postulated a continuum ranging from laissez-faire to complete prescription of the elementary, junior-high, and senior-high science programs in Manitoba. Voss (1958) used questionnaire, personal visit, and interview to survey the status of science education in Iowa high schools.

Redfield (1960) made a comparative survey of programs, facilities, and staff of secondary-school science departments by use of a stratified random sample of four public schools in each of seven geographical strata. The procedure involved preparing the sampling design, inviting co-operation of the schools, visiting 57 schools for three hours each, interviewing administrators and teachers, and inspecting laboratory and library facilities.

Experimental Research

More than 26 percent of the studies examined were experimental. Few adhered to all the principles of replication, randomization, and control of variability as advocated by Johnson (1951). In still fewer were the assumptions underlying the statistical treatment adequately tested.

Gibb and Van Engen (1959) followed Johnson's principles when they drew a sample of fifth-grade children from 30 schools, divided them into three groups of 8 boys and 8 girls each, and provided three structured experiences individually for the children in helping each develop the mathematical idea of area. There was replication of treatment within each group. There was randomization in the selection of the sample, in the assignment to groups, and in the method of instruction for each child. Variability was controlled by restricting the IQ range to 100-110 and reading ability to equal to or greater than grade 3.5 and by other restrictions relating to location of school and homogeneity of classroom. The unit instructional scene included child, instructor, and assistant, with a tape recorder for all conversations. Analysis of variance was used extensively in comparing the results.

Anderson and Montgomery (1959) took care in testing assumptions by using normal-probability paper for showing normality and the Bartlett test for homogeneity of variance and regression, with the result that the analyses of variance and covariance that followed were on a sturdier foundation than is usually the case. Analysis of variance was used in analyzing pretest to post-test variance increases.

Two-Methods-of-Teaching Comparisons

Two methods of teaching the determination of the characteristic of a common logarithm were compared by Clebowicz (1958), who applied an extension of the Johnson-Neyman analysis to three matching variables. Graphs described three-dimensional regions or ranges of values for each background trait wherein the difference in achievement between the two treatment groups was significant. Clebowicz found the *time* element to be a significant factor in learning. Dearden (1959) also used the Johnson-Neyman technique for combining findings from six sections and thus compared the treatment groups for the experiment as a whole. Pretests, post-tests, and delayed post-tests were used.

Jensen (1958) compared two treatments using the same curricular content over a two-year period. Random samples were checked for equivalence in intelligence and in reading ability by use of a modification of the Welch-Nayer test for homogeneity of variances, and by analysis of variance for testing equality of means. Pupils were randomly assigned to classes for each year. Teachers were randomly assigned the first year, and they taught by contrasting methods the second year. This enabled an extension of the unrestricted randomized design to be used in setting up a three-way classification system for analysis.

Kuhnen (1960) used a rotation technique, each contrasting group being experimental for three weeks and control for three weeks, in assessing the effectiveness of field trips in the teaching of botany. Criteria for selection of areas for field work were established by a jury.

Nonparametric statistics were used in a science-film study by Popham and Sadnavitch (1960). Use was made of the Mann-Whitney *U*-test, the sign test, and chi-square. Schools were divided into two groups matched for grade organization, student enrollment, assessed-property evaluation, community population, type of accreditation, and number of full-time faculty members. Achievement was compared by analysis of covariance, holding constant pre-experiment achievement, grade-point average, and intelligence.

A Laboratory-Type Study

A transfer-of-training design was used by Ervin (1960) with 16 third-grade and fourth-grade children, whose problem was to predict the action

of a body on an inclined plane. A standardized verbal interrogation was conducted. Apparatus included a truck weight, a counterbalance weight, and a plane whose inclination could be varied. The children were trained in predicting the outcome of variation of two variables when the third was held constant, and then were tested on a second problem in which all three were varied.

Research Leading to the Development of Methods of Instruction and Courses of Study

About 17 percent of the studies dealt with proposed methods and courses in science and mathematics.

Jackson and others (1960) conducted five projects designed to increase students' independence in learning. The biology project sought techniques or devices that would enable students to design and conduct appropriate laboratory experiments with increased self-direction. A sample of 22 students aged 13-16 with IQ's above 100 were set goals, assigned tasks, and taught research techniques. The instructor acted as consultant and did some conventional teaching—all in five 56-minute periods and two field trips. The chemistry project, with the theme "The key to permanent learning is relatedness," was a two-year effort, the first year being devoted to developing materials and testing the hypothesis that self-dependence of students in the laboratory increases with a concurrent decline in the necessity for close supervision. Measurements of acquisition of facts and increase in self-direction were made in the second year. This experiment was reported by Westmeyer (1960).

Mitchell (1959) developed an integrated science course for nurses by drawing up a checklist of items in chemistry, microbiology, anatomy, and physiology. The checklist was submitted to nursing educators, curriculum consultants, junior-college instructors in these fields, and senior students in three schools of nursing. A shorter questionnaire was sent to graduates of the hospitals. Standard scores were derived to estimate the value of each item on the checklist.

Predictive and Correlational Studies

About 7 percent of the studies examined dealt with the relationship of an individual's characteristics to later achievement.

Oakes (1959) used the Wherry-Doolittle method to calculate multiple-regression equations in score form to predict the contributions of intelligence, interests, aptitudes, previous academic experience, reading level, and personality to the academic achievement of gifted seventh-grade children in an accelerated general-science curriculum.

Bradley (1958) used the IBM 650 computer with a multiple-regression program to estimate success in technical and skilled-trade courses. Output

included means, standard deviation, zero-order correlations, predicted scores, residuals, and standard errors of multiple estimate. The 42 variables in the initial phase were reduced to the three most independent ones in the final phase.

Cooley (1958) showed how the attributes of potential scientists might be discovered through the application of multivariate analyses (discriminant analysis, analysis of variance, regression, and factor analysis).

Historical and Philosophical Studies

At least 7 percent of the studies examined made use of historical or philosophical methods.

Carlton (1959), by historical analysis, determined the educational concepts of 14 outstanding mathematicians between 1790 and 1940, which emerged from their psychological, historical, and pedagogical viewpoints; their creative thinking in terms of habits and traits; and the role of symbolism in their thinking.

Philosophically, Obourn (1960) saw a crisis in science-education research because "we . . . persist for the most part in being content with incidental, piecemeal and fragmentary research which nibbles away on the outer edges of the basic issues while the central nucleus of these unresolved issues builds up into even more formidable proportions. . . . May we not with some profit take a lesson from pure science research where issues of broad scope are identified, resolved into more specific problems, and then attacked on a team basis for solution?" (p. 21). Some broad issues are assessment of objectives, relative importance of criteria, needed changes in methods, general attributes of potential scientists, needed research, and methods of implementing research. Whether or not efforts can be co-ordinated as Obourn believes necessary is an open question. The nearest thing to co-ordination occurs in the annual meetings of AAAS, AERA, and the various associations of teachers of science and mathematics.

Large-Scale Studies and Projects

Institutes, seminars, and curriculum projects and large-scale studies make use of a number of methods of research, but such reports constitute a very small proportion of the studies examined. Among large-scale studies, Wittich and others (1958) acted as a committee to evaluate films used in physics classes. In Kansas, several studies were made involving 300 high schools and 7000 juniors who took the *National Merit Scholarship Qualifying Test* in 1958. When these students became seniors in 1959, they completed a questionnaire prepared by the University of Kansas Bureau of Educational Research and Service, giving a 66 percent (4700) return. In one study, Sanderson and Anderson (1960) selected 100 mathematics

and 100 science students from the respondents who felt they had had inspirational teachers and compared them with 100 who felt they had had noninspirational ones, with reference to group achievement.

A large-scale follow-up survey by LeBold and others (1960) sought information regarding postcollege experiences of the engineering graduates of Purdue from 1911 to 1956. Alumni, faculty, senior students, and freshmen made up four distinct populations, each member receiving a printed questionnaire, a deck of serialized mark-sense IBM cards, and other materials. Size of sample was 6200.

University of Wisconsin arithmetic studies were made at fixed ages for pupils of high, average, and low intelligence. Measures of acquisition, five-minute retention, and six-week retention were made for each intelligence level. A typical study was that of Klausmeier and Feldhusen (1959), who investigated retention at 117 months of age.

Summary

For the period under review, educational research studies in science and mathematics occurred in the following order of percentage frequencies: survey, 39; experimental, 26; development of methods and courses, 17; predictive and correlational, 7; historical and philosophical, 7; large-scale studies and projects, 3; test construction and measurement, 1.

The foregoing distribution is a picture of the existing situation, not necessarily what should be the configuration of educational research in science and mathematics. In many studies, the problem of equivalent group sampling was not met well. Several researchers attempted to match individuals on the basis of one or two characteristics instead of drawing samples at random from a specified population. Assumptions underlying statistical analyses were adequately tested in only a few studies.

It is often contended that performance of research as part of the requirement for a doctorate is more important than the result, in that the degree attests to the candidate's ability to perform research. Nevertheless, studies which revealed nonsignificant differences among methods or treatments or made inferences on the basis of poorly selected samples were disconcertingly frequent. Here are some suggestions:

1. Introduction of the *time* element. If Method A develops more learning and retention than Method B within the same time, or if complete learning can be obtained in a shorter time by Method A, then Method A is superior. When the amount of content dealt with in our schools is under question, importance of the time element cannot be controverted.

2. Examination of changes in variance, e.g., Lucow (1960), as a way of deriving significant results from the data when differences in means turn out to be nonsignificant. If Method A produces the same average result as Method B but allows the expression of individual differences to operate as measured by increase in variance to a greater extent than does B, then A is the superior method.

3. Use of available sampling techniques. As noted, surveys constituted the largest category of studies. Many purported to be analytic, with intent to draw statistical inferences. Yet careful attention to representativeness was not usual. Techniques such as stratified random sampling are well known, and the selection of a sample to represent a population is one of the important steps.

4. Use of the newer multivariate-analysis technique, such modes of statistical operation as partial and multiple correlation, analysis of covariance, and the discriminant function. Factorial design permits stratification of data and the testing of interactions. It is possible to vary all essential conditions simultaneously rather than one at a time, thus yielding greater efficiency and comprehensiveness. The results have wider applicability than those of single experiments, since the latter give information only in respect to a narrowly restricted set of conditions.

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